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The Cover: Electric control equipment sails the seven seas in the "baby flat-top," a refitted cargo vessel.

Allis-Chalmers photo

TRANSACTIONS SECTION

(Follows EE page 86; a preprint of pages 41–86 of the 1945 volume)

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ELECTRICAL ENGINEERING
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Technology in Postwar Expansion

WILLARD CHEVALIER

Maintaining production at a high level is the key to expanding the American standard of living and extending its benefits to more of the people in the postwar period, declares this author. If we keep open wide the doors of opportunity, security will take care of itself, he contends. The tasks that the postwar world poses are tasks in which engineers, as well as capital, labor, and management, all have their responsibility.

NOT so many years after photography was introduced to the world, George Eastman revolutionized the infant business by offering to do the developing of the negatives and the printing of the pictures in Rochester. He brought photography to the people with his slogan: "You press the button; we do the rest."

It seems that this slogan really should belong to the electrical industry, for the pressing of a button long has been the means of releasing electric energy for productive purposes. But when one reads of the progress made in electrical engineering in recent years, one realizes that this slogan "You press the button; we do the rest," already is a bit out of date. The trend in electricity seems to be to do away with the necessity of pressing a button or turning a switch. An electronic tube, quite likely, can be given that job and can start or halt the flow of electricity more rapidly and more efficiently than when this task is entrusted to human hands and brains.

The very mention of the word "electronics" lays open a vast field for speculation as to its particular part in the broader program for technology in the postwar world. Unfortunately crystal gazing has its disadvantages. The prophet who looks into his globe and sees electronics doing most of the work of the home and the factory of the future should have another crystal ball handy into which he could peer and determine the date upon which these developments will be available to the customers.

ENGINEERS HAVE REALISTIC APPROACH

Engineers have just as good imaginations as the best of the Sunday feature writers, but they have a more realistic approach to the time element involved. If engineers fail to act, we cannot have any of these new good things that have been promised us. However, engineers alone cannot give us these things—producing them will require the wholehearted co-operation of capital, labor, management, and the consumers.

Essential substance of an address made before the AIEE San Francisco Section, San Francisco, Calif., October 13, 1944.

Willard Chevalier is vice-president and director of McGraw-Hill Publishing Company, Inc., New York, N. Y., and publisher of *Business Week*. He served as lieutenant-colonel of the 11th United States Engineers during World War I.

The eventual consumer of electricity knows very little about it. Electricity is a mystery subject to the average person and so one hears some rather unusual ideas expressed about it from time to time. But because it is all about us, in so many forms, it is of extreme interest to the individual, and the more information, in nontechnical terms, about electricity that is made available to the average man, the better he will be able to understand the engineer's attitude and problems.

Gilbert D. McCann of the Westinghouse Laboratories explained recently, in simple terms, that the value of lightning was not in the amount of potential electric energy that might be harnessed, but in the fact that when lightning shoots earthward it releases nitrogen from the air. About 100,000,000 tons of nitrogen annually are absorbed into raindrops and fall to the earth, enriching the soil so that we may have food. More nourishment for the earth is provided by lightning than by all of the world's fertilizer plants. Information such as this, when given widespread circulation, tends to reduce the number of fantastic ideas that are offered to provide a world with "free energy" through the harnessing of the highly erratic power that all of us know *does exist* in lightning.

The job of education should extend beyond the field of electricity, however. There are just as many impractical notions afloat in the whole broad field of technology.

One of the most dangerous predictions about this bright new postwar world that technology and science can provide for us is that the final result will be less employment for the people. A report on a speech made by an Army officer recently pictured a postwar world with television sets, combination heaters and coolers for stable temperatures, plastic furniture and dishes, dustfree air in sealed homes, and beam-power transmission for low-powered electric devices. But, this speaker warned, these labor-saving devices will tend to create a critical unemployment situation. The one tenth of the population continuing to be employed and having all it needs will forget that the other nine tenths also must make a living, he said.

EMPLOYMENT A POSTWAR PROBLEM

Already we have seen some labor leaders going on record as favoring the 30-hour week as a means of spreading the work so that more people will have jobs in the postwar world. Too many are working on the theory that all of the new gadgets that have been promised us will be available with the defeat of Japan and that, as a result, there never will be enough jobs to go around.

But what are the facts? Let us look at a typical industry. Only once in the history of the automobile has that industry had an average 30-hour week. That was in 1932, when total payrolls in the automobile manufacturing field were the lowest they had been at any time since the start of the first World War. That was in 1932 when the average weekly earnings in the automobile industry were the lowest, except for the following year, of any year between the first World War and the present time. That was in 1932, when the number of motorcar registrations showed the greatest decline in the history of the automotive business, at least until production was completely shut off early in 1942.

It is true that we could put more men to work producing automobiles if we were to return to the production methods that existed back in the early part of this century. But would we have a market for automobiles so produced?

We may be able to find the answer from the experience of one of the pioneers in the automotive field. In 1908 it was pro-

ducing a limousine for $5,000, a very fine product for its day. But in 1937 it turned out a much finer car for $1,200, less than a quarter as much. Was this because of the greater skill of the workers? Quite probably those old-time automotive workers had a greater degree of hand skill than those who turned out the better and cheaper car in 1937.

INCREASED EFFICIENCY—DOUBLED OUTPUT

I think the more logical answer for this improved and cheaper product is found in the fact that this company recognized the necessity of increased efficiency and spent huge sums to install an assembly line. It purchased and built special tools and dies and jigs, and mammoth presses and hammers. Through this expenditure for new machines and improved methods the company was able to double the value of output for each worker between 1908 and 1937. And at the same time that the output was doubled, the annual wages of the workers were tripled.

The important thing to remember is that this increase in wages and a gradual lowering of the number of hours for the workers came as a result of producing not less, but more, thanks to the investment of additional capital in more efficient machines and methods. The actual return to investors probably showed little or no increase—it may even have shown a decline—between 1908 and 1937. But in those same years the return for the workers and for the customers was tripled and quadrupled.

We have seen that the automobile became an essential in our vast transportation system, not because we produced fewer automobiles, but because we produced more of them. It seems logical to assume, therefore, that those who forecast the doom of the American standard of living as a result of overproduction may be on the wrong track.

SEEK MEANS OF PRODUCING MORE

It would seem that, if we, as engineers, as automotive workers, or as laborers in any field, were seeking the solution of the problem of expanding the American standard of living and extending its benefits to more and more of the people, we should seek means of producing more. This makes sense, because only by *producing* more can we employ more men in useful jobs. Only by *producing more* can we have *more to sell.* Only when we have *more to sell* shall we have *more to distribute* in the form of wages to the worker. And to those who say: "But we must provide security for all," we can reply that if we keep open wide the doors of opportunity security will take care of itself.

In the final analysis, the only way we can insure greater security is to add more to the nation's stock of goods. This applies equally to the engineer, who creates; the capitalist, who invests to make ideas turn into actual products; and the worker, who operates the machine that makes the process possible. If we are agreed that we can make this a better world to live in by producing more, let us see what each of us shall have to do in order to achieve this better world.

WHAT IS FULL EMPLOYMENT?

The worker may say he is interested primarily in full employment. So, what do we mean by full employment? Full employment could mean that every man, woman, and child in the United States would have to be provided a job and presumably draw wages. Full employment could mean that every one would have to be on the job every minute. Even machines cannot keep that up forever. Even if we define full employment as meaning that every able-bodied person over a certain age shall be kept at work, I doubt very much if that is what we want. For the only way we can achieve such a degree of employment is to have a totalitarian government with the power to say: "You *must* work, and here is *where* you shall work; this is *what* you shall be paid, and this is *what* you shall produce."

As long as we remain a free people, and the individual is free to work or go fishing, as he may elect, or go into business for himself, or to work for another, or to tell one's boss off, and go down the street and look for another job—in short, if we are to remain free to find our own places in the national economy—we shall not have full employment in that sense.

Actually what the worker wants is a sustained high level of employment. He wants a level of employment so high that he will never have to fear that if he quits a job—for whatever reason—he will not be able to get another one as soon as he needs it.

The worker will want no full-employment plan that will prevent him from taking the summer off so he may load up the car and see America if he and his family desire. The worker will want no full-employment system that will prevent him from working hard all summer so that he may take it easy in the winter, if that happens to be his idea of the way to achieve happiness.

No mass-security plan is ever going to be popular in the United States if it limits the productivity of the man who wants to get ahead by working a little harder to that of the man without ambition.

HIGH LEVEL OF EMPLOYMENT

Capital also must seek a high level of employment if it is to fulfull its true mission in the postwar world. The day when capital can increase itself through manipulation of pieces of paper should be gone forever. If capital is to expect a return, capital must apply itself to truly productive effort. Capital must not seek security by protecting investments in machines or methods that *were* good. Capital must look for new machines and new methods that will produce more things at the same cost and better things at lower costs, for capital, like labor, must depend upon increased production and increased sales for its livelihood.

DUAL ROLE OF SCIENCE AND TECHNOLOGY

Science and technology have a dual role in the postwar expansion. Science, the creator, must work hand in hand with science, as represented by efficient management, if the wealth provided by capital and the work provided by labor are to be fruitful. The opportunities for technology in the field of creation appear to have no limits at the present time. What was regarded as impossible only a few years ago is now commonplace. Actualities in the postwar expansion may be only ideas today.

The United States and the Allied nations agree that our great war record would not have been possible had it not been for science and technology. But do we all realize that this great triumph on the battlefield is not the result of new scientific knowledge, but the result of the utilization of knowledge that has been accumulated since the first records were preserved.

Science is virtually unique in that it has no obsolescence problem. Stockholders in a factory may find it necessary to scrap machinery worth thousands of dollars and install new equipment, because a competitor down the street found a better way to turn out a product. Technology, in the process of creating new jobs, occasionally forces the closing of factories and workmen lose jobs and all contact with what went before. But science does not obsolete old knowledge as the new is acquired. Theories may be disproved and go into the discard, but facts and experience never wear out. Facts, discovered yesterday, are no more valuable than those known since the beginning of recorded history. The future of science, in fact, will depend not nearly so much on the discovery of new facts as on finding new applications of what is already known.

The world has been loud in its praises of the accomplishments of science as a means of speeding this war to a victorious conclusion. These accomplishments have been made possible, in many instances, because of the speeding up of research. Many of the products that went out of the laboratory directly to the battle front are five to ten years ahead of their normal time.

INDUSTRY INDEBTED TO RESEARCH

As industry faces the postwar period it will be able to take advantage of much of this war-inspired progress. Industry is going to get peacetime dividends from war. That is why industry has an obligation to put more back into scientific research so that there shall be no diminishing dividends in the future. On all sides we see indications that there are dangers ahead if this obligation is not met. Educators

point to the decline in enrollment of students in science as a result of the war. This means a decline in scientific research a few years hence, for researchers cannot be made overnight. Research workers worthy of the name must remain longer at the storehouse of knowledge than workers in many other fields, for researchers cannot dismiss the past as they look to the future. Research cannot obsolete old equipment when new equipment is available. Research can only add to its store of raw materials as the engineer and the inventer look for new ways to produce new things that the people will want and need.

ROLE OF SCIENCE IN MANAGEMENT

Science also must play its role in management, in providing for efficient use of the things that are created. Science in management is a comparatively new concept on the American scene. For many years the public was led to believe that the scientist and the engineer were types apart from the humdrum business world. But with the passing of the years there has been increased recognition of the fact that scientific treatment of day-to-day problems can and does result in more efficiency, which leads to more production, and to more jobs.

It is said that no other nation in the world today, has more men than we have in private and commercial laboratories engaged in planning for peace. We all know that new jobs are being discovered for electricity to do. This is good, for if science is not given a chance to work in behalf of all of the people we cannot achieve the highest possible production, the highest possible employment, and the highest possible efficiency. But science will not have served this country best merely by creating. It must take its place in management to help integrate the efforts of capital and labor with the technology it creates.

MANAGEMENT A FUNCTION—NOT A CLASS

It is unfortunate that to many people "management" has come to be synonymous with "employer." As a result these people see management and labor as natural antagonists and efficient management as meaning no more than additional profits in the pockets of the employers. Efficient management, of course, draws men from every walk of life, and every level of society. Management is not, in itself, a group or a class. Management is a function.

Ever since men began to work together to common ends, their chief problem has been to direct their efforts so they might obtain more of the things they wanted than would be possible if each had worked for himself alone. The solution of that eternal problem is the function of management.

Without management, the 5, the 50, the 5,000, or the 500,000 men and women who constitute any business enterprise might be milling about in futile activity—spending their energies, consuming their food, wearing out their clothes, using up their goods and tools—and, in the end, have nothing to show for it but their pains.

When you hear the statement, "Labor creates wealth," bear in mind that you have not heard the whole story. All labor consumes wealth, too. It is only directed labor—managed labor—that creates more wealth than it consumes.

Management has many duties. It must plan and provide the facilities needed to multiply the fruits of our labor. It must select and train those best qualified to work together. It must direct and supervise the day's work, always keeping in mind the relation of one day's activities to the master objectives. It must impose discipline—that is, it must have the authority to hold each individual to his share of the task. It must seek out markets and prevail upon others to want the product of its particular workers, in exchange for that of their own.

Under the original concept of engineering, its participation in management might end with the planning and the provision of the facilities. But in the electrical field, we all recognize the importance of engineering in providing efficient means for distribution of our products. Here engineering plays an important part in marketing.

FOREIGN TRADE IN POSTWAR EXPANSION

Electrical engineering is likely to play a still more important part in marketing in the postwar expansion, because foreign trade in the electric-equipment field is one of the many in which American manufacturers feel they may have an advantage. One reason for this is their ability to send out their salesmen in full confidence that they can back up the salesmen with technical superiority.

A recent survey by the Department of Commerce estimated that a foreign export trade of $7,000,000,000 can be realized in the postwar period. The department set the goal for electric-equipment export at $195,000,000 annually, divided roughly as:

Radio receiving and transmitting equipment, 17 per cent.

Generators, transformers, and so forth, 14 per cent.

Electric refrigerators, 12 per cent.

Electric motors and controls, 12 per cent.

The remainder in primary and secondary batteries, household appliances, and wiring and wiring devices.

France alone has a program involving the expenditure of some $270,000,000, designed to restore electric service in all towns with a population of more than 30,000. The Russians have announced a program calling for 559 generating stations totalling 2,706,000 kw.

A more recent private survey says the $195,000,000 export business in electric equipment may be overoptimistic, but agrees that the figure *can be reached* if American businessmen make a *vigorous effort* to attain it. Even if the total reaches only $165,000,000, it will be 30 per cent greater than in 1929 and 60 per cent above 1939. It would appear there is an unequaled opportunity to build enduring trade relationships.

NEW USES FOR MOBILE POWER PLANTS

At least two of the major electrical manufacturing firms in the United States are now producing mobile electric-power plants of 3,000 to 5,000 kw capacity. Such plants are being purchased by the Soviet Government and by our own military forces to serve communities while sabotaged power plants are being rebuilt.

It is quite probable that new uses for mobile power plants will be found after the work of rebuilding Europe has been completed. Certainly there is reason to believe that application of inventiveness and engineering ingenuity will result in opportunities for practical applications of mobile power within the United States.

ELECTRICAL ENGINEERING IN AVIATION

We are all familiar with the importance of electrical engineering and design in the aviation industry. A recent report said that in 1932 radio and communication represented 20 per cent of the total expense of commercial aircraft maintenance and operation. Now it represents 60 per cent of the total.

Midget motors operating at frequencies higher than the accepted 60 cycles have proved desirable in airplanes, because they can be made smaller and lighter than the conventional models of only a few years back. There is talk now about electric drives for airplane propellers, with generators in the fuselage and the transmission of power to small motors that would permit more efficient streamlining. This is not practical yet, but electrical engineers and metallurgists have a challenge here. They face the problem with the realization that airplane designers approve the idea of a central power plant, instead of two or four in the wings, because it would help them produce a better-balanced airplane. But at high altitudes electricity performs differently than it does at sea level. As air density decreases, destructive arcs develop at lower voltage. Operation of airplanes in the tropics and in the arctic, at sea level and at high altitudes as a result of the war certainly has helped to solve some of the problems of heat, cold, and humidity that would have baffled us as late as 1941.

MYSTERY OF ELECTRONICS

There is considerable mystery about electronics, among electrical men; their place in the postwar world is not a secret just because military secrecy has forced us to be quiet about certain applications. There are many instances of manufacturers

being refused knowledge of the use to which certain apparatus is being placed, because the inventer wants to keep his secret.

SECRET FORMULAS OF EARLY DAYS

A small rubber manufacturer said recently that the business secret was the principal stock in trade of some of the rubber manufacturers in the early days. Spies were sent into plants in the hope of obtaining the secret formula. Gradually certain manufacturers agreed to exchange information, in the hope of improving their own products and found that, often, they had been guarding the same secret. The war brought an acute rubber shortage, and further interchange of information became essential if we were to survive. Technicians from the major companies went into small plants, and owners of small plants were welcomed to the major factories. They found that the "secret formula" was not the true secret but what one did with a formula, based on fundamental laws of chemistry and physics, was what really counted.

For many years the photoengravers prided themselves on the secrets they held in the various phases of the process of converting a photograph into a zinc or copper plate, from which thousands of copies could be printed. There was no such thing as an all-around engraver. There was the camera man, the developer, the etcher, the re-etcher, each with his own little bag of tricks. Then one day an enterprising promoter developed a one-man engraving plant after somehow managing to acquire enough basic formulas to permit him to put a comparatively inexperienced man in charge of it. Before the war came on, scores of small newspapers about the country that, under no circumstances, could afford the four or five men required to operate the old-style engraving plant started turning out local pictures, because they *could afford* one man to run the whole show, and possibly act as staff photographer, in addition.

APPLICATIONS OF ELECTRONICS

There has been considerable publicity on the use of electronic heat in speeding of production of penicillin, new wonder drug needed by our Armed Forces and civilians alike. There have been forecasts that electronic heat some day may be used to dehydrate foods on a commercial basis; that it will help to cook our postwar steaks. But a good many applications of electronics, in heating and in motor and machine control, are still being produced on a custom-built basis to individual specifications. The result is that the manufacturers are unable to turn out a packaged product in sufficient volume to permit widest possible application and to get prices down to the lowest possible level. Whether the future of electronics will be hampered because of wide application of the "business-secret" theory is still to be determined.

It seems that the future of the engineer in electronics, or in any other phase of the application of electricity to productive purposes, depends on just two things:

1. How alert his firm is in recognizing that it can never be satisfied with a good thing, even if it thinks it is the only firm that has it.

2. How alert the engineer is to the necessity of adding to his store of knowledge and finding new applications for what he already knows.

No firm can afford to stand still. If it is not always working on a program to obsolete what it has and to produce something better, or cheaper, it may rest assured that the competitor down the street, or across the nation, is doing that very thing. No engineer can be satisfied merely by bringing himself up to date on the developments in the field of electricity. He must not, in fact, confine himself to electricity. He must search out opportunities to apply the potentialities of electricity to fields that are not now even considered within the realm of his activities.

Electricity, and technology as a whole, have made rapid strides in recent years. But there can be no resting on the oars now. The American people expect still greater things in the future, and they will expect engineers to assume their full share of the task of providing a postwar world that is geared to high-level production, with its attendant high-level employment. This can be made possible only by high-level efficiency. And it is in the field of efficiency that the engineer's greatest opportunities are limitless.

High-Frequency Heating of Conductors and Nonconductors

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To heat electric conductors made of metals—iron, brass, aluminum, and so forth—the piece to be heated is surrounded by a coil carrying the high-frequency alternating current. This coil induces the heating currents in the work, and the process is called induction heating. The frequency used depends on the physical properties and dimensions of the piece to be heated.

To heat the so-called nonconducting materials such as wood and Micarta, the material is placed between high-voltage plates to form the dielectric of a capacitor. Heat generated in the material is dielectric loss, and the process is called dielectric heating. The frequency used depends principally on a measurable quantity called loss factor and the rate of heating desired. Whereas induction heating is inherently nonuniform heating, dielectric heating finds its greatest advantage in the fact that it gives almost perfectly uniform heating throughout a mass of material.

Essential substance of a paper presented before the National Electronics Conference, Chicago, Ill., October 5–7, 1944.

R. M. Baker is section engineer, research laboratories and C. J. Madsen is electronic engineer, industry department, both with Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

INDUCTION HEATING

Because this is a general discussion of induction-heating applications, the theory of induction heating will be presented in the simplest possible manner. The presentation will consist in the statement of a few facts, the proof of which can be found in any treatise on skin effect.

A typical arrangement for induction-heating a metal cylinder is shown in Figure 1A. In this representation, a coil of hollow copper tubing is close wound to form a helical coil around the piece to be heated (work piece). In order to reduce the coil voltage to a minimum and obtain good coupling to the work, the coil should conform as closely as mechanical and electrical considerations permit. Since high currents are used for induction heating, the coil is almost always water-cooled.

Alternating current flowing in the coil causes a countercurrent to flow in the work as indicated by the arrows of Figure 1A.

If the frequency is high enough, the coil current will concentrate near the inside surface of the coil, and the work current will concentrate near the surface of the work piece. This effect generally is referred to as skin effect.

DEPTH OF CURRENT PENETRATION

In Figure 2 is shown a graph of the current density near the surface of the work. It is a maximum at the surface and dies off exponentially below the surface. Mathematical analysis shows that the total heating of the exponentially distributed current density is the same as would be produced by the same total integrated current flowing in a shell or layer (δ) inches thick, where δ can be calculated from the equation:

$$\delta = 3{,}170\sqrt{\frac{\rho}{\mu f}}\ \text{inches} \tag{1}$$

ρ = electrical resistivity (ohm-inches)*
f = frequency (cycles per second)
μ = magnetic permeability

This is called the depth of current penetration and becomes a useful concept in calculating induction-heating applications as will be shown later.

POWER GENERATED IN WORK

For the condition illustrated in Figure 1A (δ small in comparison to the diameter of the work piece) it can be shown that the total current flowing in the work is equal to the total ampere turns in the magnetizing coil. Thus if the coil carries 500 amperes and has ten turns, the current flowing around the periphery of the work piece will be 5,000 amperes. The heating can be calculated according to the last section by assuming that this total current flows in a layer (δ) inches thick. The resistance to the flow of this current is thus

$$R_w = \frac{\rho p}{\delta l_c}\ \text{ohms} \tag{2}$$

and the total power input is

$$I_w^2 R_w = (AT)_c^2 R_w\ \text{watts} \tag{3}$$

p = average length of current path (inches)
l_c = length of coil (inches)
$(AT)_c$ = rms ampere turns in coil

The density of heating can be obtained by dividing equation 3 by the surface area of the work piece under the coil. Thus,

$$\text{Watts per square inch} = (NI)^2\frac{\rho p}{\delta p'} \tag{4}$$

p' = outer perimeter of work piece (inches)
N = turns per inch in coil
I = rms amperes in coil

For the case shown in Figure 1A, p' is practically equal to p, but equation 4 is fairly accurate when δ is as great as one-third the diameter of the cylinder, and for this case p' will be considerably greater than p.

* Ohm-inches = ohm-cm/2.54.

If reference is made again to Figure 2, it is seen that a large part of the total current flows within a depth (δ) below the surface, and from the curve of relative heating (current density squared) it is seen that an even greater part (86.6 per cent) of the total heating occurs in this depth. Thus δ given by equation 1 not only is a convenient quantity for calculating power generated, but also gives a good indication of the depth of heating. The rate at which heat flows out of the region in which it is generated will be discussed later.

The convenience of equations 1, 3, and 4 lies in the fact that they may be used equally well to calculate the heating in other regular and irregular work pieces as indicated in Figure 1, B, C, and D.

To calculate approximately the power input to various metals equation 4 may be simplified by assuming $p' = p$. Thus,

$$\text{Watts per square inch} = (NI)^2\frac{\rho}{\delta} \tag{5}$$

or if the value of δ is substituted from equation 1,

$$\text{Watts per square inch} = 3.16\times10^{-4}(NI)^2\sqrt{\mu f \rho} \tag{6}$$

INTERPRETATION OF μ IN EQUATIONS

Metals like copper, brass, and aluminum, which commonly are called nonmagnetic have a magnetic permeability of unity, and to calculate heating or depth of current penetration in such a metal one simply substitutes $\mu = 1$ in the formulas.

For ferromagnetic metals like iron and nickel, experiments indicate that the value of μ to use is approximately 1.78 times the permeability at the surface taken from a magnetization curve for the particular value of ampere turns per inch used in the coil. For iron this value of μ is given for ampere turns per inch greater than 100 by the formula,

$$\mu = \frac{45{,}700}{NI} \tag{7}$$

When the temperature of iron is above 780 degrees centigrade, it loses its ferromagnetic properties and becomes paramagnetic (commonly called nonmagnetic). When calculating heating or depth of penetration of current for this case, one simply substitutes $\mu = 1$ in the equations.

The theories of induction heating of metallic electric conductors and of dielectric heating of nonmetallic nonconductors are discussed in simple terms in this article for the benefit of those who are not specialists in this field. The various types of high-frequency heating, its applications to industry, and its advantages in economy, efficiency, speed, and adaptability are pointed out.

LIMITATIONS OF EQUATIONS

The simplified equations already given are strictly accurate only when the depth of current penetration calculated from equation 1 is small in comparison to the minimum dimension of the piece to be heated; however, they are sufficiently accurate for most work when the depth of current penetration is equal to or less than one-third the minimum dimension.

The equations for power input are strictly accurate only for coils long in comparison to their diameter or minimum dimension. For short coils, the power input per square inch will be less than indicated by the equations. Stated another way, the value of ampere turns calculated from the equations is the minimum value to give the desired power input and should be increased for short coils. A discussion of this effect will be found in several references listed at the end of this paper.

SPECIAL CURVES FOR IRON

A large percentage of induction-heating jobs involve heating iron or steel. Special curves giving power input per square inch at standard frequencies as a function of ampere turns per inch in the coil, for iron in the ferromagnetic condition (temperature below 780 degrees centigrade), Figure 3, and for iron with a permeability of unity (temperature above 780 degrees centigrade), Figure 4, are calculated from equation 6 and the average resistivity of iron in the respective temperature regions.

The depth of current penetration for iron below 780 degrees centigrade (ferromagnetic region) as a function of ampere-turns per inch in the coil is given by the curves of Figure 5.

The depth of current penetration in the paramagnetic region (above 780 degrees centigrade) is not dependent on magnetizing force, and is listed in Table I for convenient reference.

COIL LOSS

If the coil is close wound from copper strap or rectangular bar stock, most of the current will flow near the inside (next to work) surface of the turns. For good coil design, the radial depth of copper should be equal to or greater than the depth of penetration of current as indicated by equation 1. The distribution then will be identical with the curve of Figure 2, and the coil loss in watts per square inch of inside surface can be calculated from equation 6, using $\mu = 1$ and $\rho = 0.79\times10^{-6}$ ohm-inch. For convenience, this equation is plotted as curves in Figure 6.

The total coil loss will be given by the triple product of watts per square inch (from curve), inside perimeter of coil (inches), and length of coil (inches). If the turns are spaced, the copper loss for the same ampere turns per inch and same

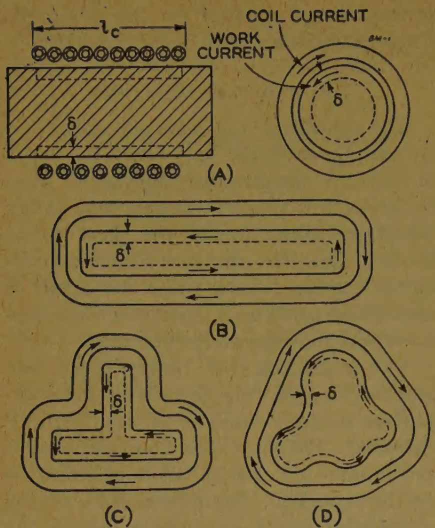

Figure 1. Induction heating of various shapes showing current paths

over-all length will be increased approximately in the ratio C_1/C_2 where

C_1 = pitch of turns (inches)
C_2 = axial width of conductor (inches)

The loss in a coil wound from hollow copper tubing will be about the same as for the strap-wound coil, provided the wall thickness of the tubing is greater than the depth of penetration of current.

For frequencies above 2,000 cycles per second, the coil usually is wound from hollow copper tubing so that it can be easily water-cooled. For lower frequencies, it is advantageous to use copper strap of suitable thickness with a copper tube soldered on the back of the turn for water cooling. One kilowatt per square inch is the upper limit of loss for easy water cooling in a multiturn coil. In the single-turn coil used in high-density heating, however, the kilowatts per square inch to be dissipated may be more than ten times this high.

CLASSIFICATION OF INDUCTION-HEATING APPLICATIONS

Induction-heating applications can be classified roughly in three groups according to the rate at which power is generated in the piece to be heated:

1. Low-density heating.
2. Medium-density heating.
3. High-density heating.

Typical of the first of these is the tin-brightening process which has so successfully used 200-kilocycle radio-frequency power to melt the thin tin surface on electrolytic tin plate. Although the process requires 1,200 kw of power with the strip running at 1,000 feet per minute, the surface density of power input is only about 240 watts per square inch of surface.

Typical of medium-density heating is the preferential hardening of large gears and the like where several kilowatts per square inch will be generated in the surface. The hardened case is generally of the order of one-eighth to one-quarter inch or more.

Table I. Depth of Current Penetration in Paramagnetic Region

Above 780 Degrees Centigrade

Frequency-Cycles Per Second	(δ) Inches
60	2.80
960	0.70
3,000	0.396
9,600	0.222
200,000	0.0485
450,000	0.0324

The very high-density heating is typified by the self-quenching technique which has been developed and publicized recently. In this process using megacycle frequencies and very high currents in a single-turn coil, power inputs of about 80 kw per square inch have been obtained.

The grouping indicated is obviously quite arbitrary, as other applications can be quoted requiring power inputs ranging from possibly ten watts per square inch to 100 kw per square inch. It is interesting, however, to note the range of requirements for different jobs.

RATE OF HEAT FLOW INTO WORK PIECE

It must be remembered that the heated region depends not only on the thinness of the shell in which the heat is generated but also on the rate at which heat flows into the heated piece. The general equations for heat flow cannot be given in the space available, but curves of temperature distribution in an iron slab for different times after one surface has been suddenly heated are shown in Figure 7.

In surface-hardening applications, it is necessary to heat the surface to hardening temperature and to have the temperature gradient at the surface steep enough, so that the metal a short distance below the surface is below hardening temperature. If the curves of Figure 7 are referred to, it will be agreed that hardening will occur to the depth where the temperature has dropped to 80 per cent of the surface temperature. The depth of hardening when heat is generated in an infinitely thin surface layer then will be represented by the equation:

$$h = 0.04\sqrt{t} \text{ inches} \tag{8}$$

t = elapsed time (seconds)

In the high-density heating for self-quenching any point on the surface is subjected to heating for about 0.1 second. If we substitute in equation 8, this gives a depth of hardening of 0.0126 inch.

The rate of heat flow is also important when it is desired to heat a mass of metal uniformly throughout. The power input must be low enough to allow heat generated near the surface to flow into the body of the material. Induction heating always generates more heat near the surface than at the center of a piece. It is important when uniform heating is desired to choose a frequency as low as possible consistent with getting good coupling to the work (δ equation 1 not greater than one-third the minimum dimension).

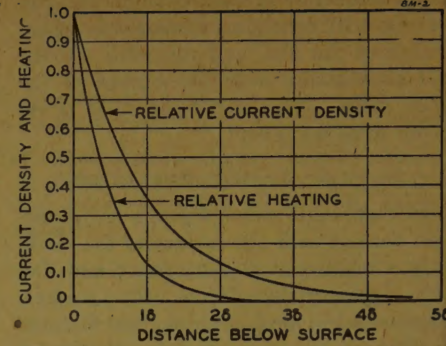

Figure 2. Relative current density and heating at various depths below the surface

$$\delta = 3{,}150\sqrt{\frac{\rho}{\mu f}} \text{ inches}$$

APPLYING HIGH-FREQUENCY INDUCTION HEATING

Induction heating is widely used in many industrial processes today. Many possible applications are still in the stage of development. Frequently a problem can be solved by the use of frequencies below 10,000 cycles. An example of this type might be the heating of steel ingots for rolling or forging. Others, such as thin case hardening, require frequencies in the millions of cycles per second.

In studying a particular problem, one of the first considerations is the amount of energy involved. A useful approximation can be obtained by the addition of the energy required to increase the temperature of the mass desired through the required temperature change, and radiation, convection, and conduction losses. The power required then can be determined by dividing this by the time involved. Neglecting radiation and conduction losses, the power can be readily obtained approximately from the equation:

$$W = K\frac{McT}{t'} \tag{9}$$

where

M = pounds of material being heated
c = specific heat
K = constant 31.6 to give W in watts
0.0316 to give W in kilowatts
T = temperature change in degrees centigrade
t' = time in minutes

Where high temperature or high-temperature gradients are involved, radiation and conduction losses must be added to arrive at the total power required. The generator rating necessary for the application depends on this total power.

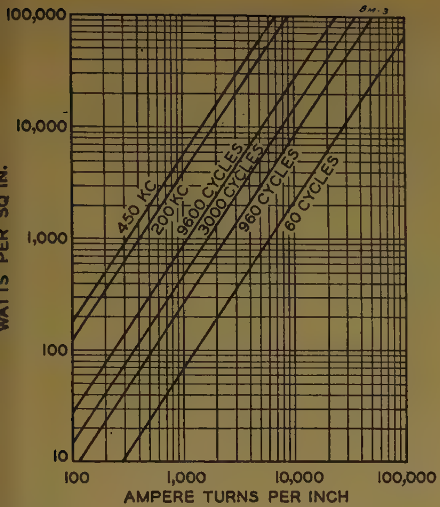

Figure 3. Induction-heating power input for iron below 780 degrees centigrade (ferromagnetic region)

$\rho = 15.7 \times 10^{-6}$ *ohm-inch*

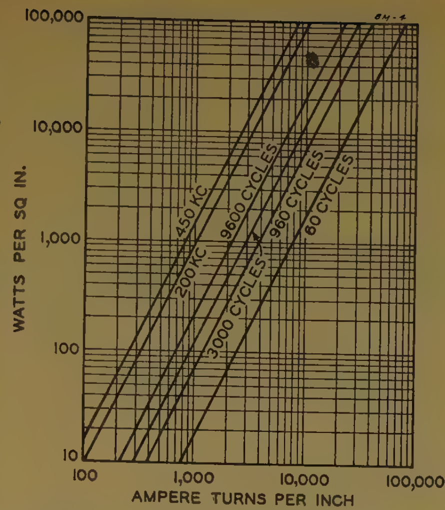

Figure 4. Induction-heating power input for iron above 780 degrees centigrade

$\rho = 47 \times 10^{-6}$ *ohm-inch*

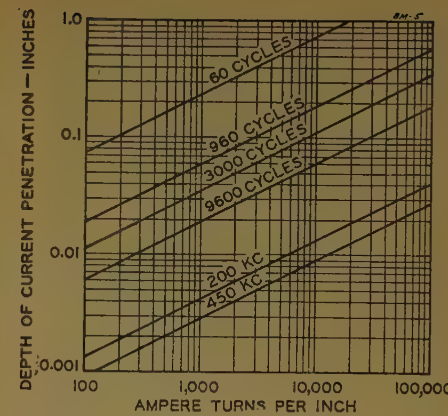

Figure 5. Depth of current penetration versus ampere turns for iron below 780 degrees centigrade (ferromagnetic region)

$\rho = 15.7 \times 10^{-6}$ *ohm-inch*

A quick estimate of the necessary generator rating may be obtained from the curves of Figure 8. These curves take into account material resistance, specific heat, and coil losses on average applications where a practical degree of coupling is obtained.

The choice of frequency, while not critical should be guided by a number of factors such as the size of the work in applications requiring complete heating or the depth of heating in surface heating cases. In the latter, the rate of heat flow into the material must be considered. The depth of the heating resulting from conduction is influenced by the time factor. Hence the power used may influence to a considerable degree the choice of frequency, or, conversely, a fixed frequency may be used for quite a variety of applications by controlling the amount of power supplied. The curves shown in Figure 9 give an indication of this phenomenon on a particular size shaft of one type of steel.

This agrees quite closely with the predictions of equation 8, although considerable deviation may be expected because of quenching technique. The material in curve 7 was water-quenched immediately after heating. The type quench and the grade of steel will influence to a considerable degree the results obtained in practice.

Coil design and construction have been covered by a number of articles and hence will not be considered here.

Occasionally problems are encountered where high concentrations of current are required in coils of one or two turns. Current transformers giving three to ten times the generator current in the secondary circuit are a practical means of obtaining higher currents in some applications of this type. Low secondary-circuit reactance is a factor which is extremely important if current ratios approaching the turns ratio are to be obtained.

Another method commonly employed to increase the coil current is the use of a capacitor in parallel with the work coil, to resonate the work circuit partially. This is an effective means of increasing coil currents up to about double the generator current.

APPLICATIONS OF INDUCTION HEATING IN INDUSTRY

Induction heating is being used today in many industries, in many types of processes. The following list of applications gives a fairly comprehensive view of the work which can be done, but it is not necessarily complete:

Annealing—metal tubing and sheet.
Bonding—clutch facings, cycle welding.
Brazing—tool tips and other products.
Chemical processes—catalysis, autoclave.
Heating for forging—bolt heads, rivets, and so forth.
Hot spinning—tube closure, and so forth.
Melting—metal alloys, tin.
Miscellaneous heating—drying painted surfaces.
Sintering—powdered metals.
Soldering—cans, bushings.
Spot annealing—die repairs.
Sterilization—surgical instruments.
Surface hardening—gears, shafts, tools, cylinders.
Through hardening—shells and tools.
Very thin surface hardening—thin-walled parts, tools, gears, bearings.
Welding—pipe and other parts.

Figures 10, 11, and 12 illustrate three of the applications mentioned.

In general, it can be said that induction heating will be advantageous when more rapid heating than can be obtained by more conventional means is necessary or desirable. Such applications include surface-hardening processes or brazing operations which make it desirable to heat only the joint to be brazed without heating the whole piece. Soldering operations also will fall into this class, and induction heating is especially attractive because an entire seam can be quickly made and automatically timed by an inexperienced operator. The surface of an oil-well drill can be superficially melted to apply a layer of tungsten carbide or other wear-resisting material without deforming or damaging the body of the drill. A steel shaft moving through a coil can have its surface heated to such a shallow depth that self-quenching occurs as the heat soaks into the body of the shaft. Thin cylinder walls can be heated on the inside while the outside remains comparatively cool, thus producing a hardened inside surface with a tough shock-resisting wall. These are but a few of the important uses found for induction heating because of the high rate of heating possible by this method.

Another good general field of application for induction heating is in continuous processes. A good example of this has been the brightening of electrolytic tin plate traveling continuously through a coil at 1,000 feet per minute or fittings being soldered to small bushings as they are fed automatically into a turntable and through an induction-heating coil. Or special cans for capacitors can be soldered as they move past a coil on an endless belt. Iron wire can be annealed continuously at 1,000 feet per minute or more. One-inch steel rod can be heated continuously as it is fed into an automatic rivet-forging machine. Or aluminum slugs can be heated continuously as they slide down a chute to be forged. These applications require sizeable power inputs at moderate density.

Induction heating has found considerable use in the preheating or strain relieving of welded joints. Much of this work has been done at commercial frequency (60 cycles per second). It also has been used for such low-temperature applications as making shrink fits.

Induction heating has been considered for heating large drums used to roll cellulose fibers into wall boards and for the heating of reaction kettles. It even has been considered for thawing ore cars which freeze up in the winter so that they

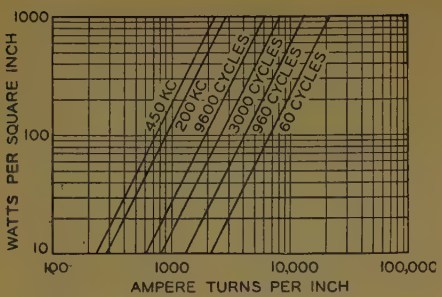

Figure 6. Copper loss in ideal coil—watts per square inch of inside surface

Curve of equation 6 with $\rho = 0.79 \times 10^{-6}$

can be satisfactorily dumped, and for heating steel ingots for rolling.

Most of the applications mentioned are very practical and economical. A few are technically possible, but the economics are questionable.

Heating of small rods (less than one-quarter inch in diameter) and thin sheet (less than one-quarter inch thick), except when these are of ferromagnetic material such as iron, steel, or nickel, is very difficult. Even these cannot be heated economically above the temperature at which they lose their ferromagnetism (780 degrees centigrade for iron) unless the finished product is especially valuable or cannot be heated by more conventional means.

DIELECTRIC HEATING

Dielectric heating is generally limited in application to those materials known as nonconductors of electricity. The piece to be heated is placed between two plates or electrodes to form a capacitor. A high voltage at high frequency (2–100 megacycles per second) is applied to the plates and heat is generated in the dielectric (material to be heated) by a kind of molecular friction brought about by the high alternating electric field. Since the field producing the stress is uniform throughout the thickness of a homogeneous material, the heating is ordinarily uniform throughout. This makes this type of heating particularly useful when thick sections are involved. Electrical engineers are familiar with dielectric heating, because it occurs undesirably in most high-voltage high-frequency capacitors; actually limiting the kilovolt-ampere rating of these capacitors.

A dielectric heating load is represented in Figure 13A by a capacitor with a shunt resistance. The current through the parallel resistor represents a power loss corresponding to the molecular friction previously mentioned and, if the dielectric has appreciable conductivity also, a loss due to the flow of a conduction current through the material.

With the voltage E applied a total current I_0 will flow into the load as shown by the diagram Figure 13B. This total current is made up of two components I_r, the inphase component and I_c, the purely reactive component. The power input will be

$$W = EI_r = 2\pi f C_0 e' E^2 \tan\delta \text{ (watts)} \qquad (10)$$

C_0 = capacitance of plates with air dielectric (farads)
e' = dielectric constant of material to be heated
E = rms volts between plates
$\tan\delta$ = tangent of loss angle for material being heated (see Figure 13)

For small loss angles (low power-factor) $\tan\delta$ is approximately equal to $\cos\theta$, the power factor of the material.

Often the product $e'\tan\delta$ is combined in one constant e'' called the loss factor of the material. When this substitution is made and C_0 is expressed in terms of plate area A (square inches) and plate separation d (inches), the power input to the work can be expressed by

$$W = \frac{1.41 A f e'' E^2 \times 10^{-12}}{d} \text{ watt} \qquad (11)$$

or

$$W' = 1.41 f e'' \left(\frac{E}{d}\right)^2 10^{-12} \frac{\text{watts}}{\text{cubic inch}} \qquad (12)$$

where E/d is the voltage gradient in the material being heated (volts per inch).

Equation 9 may be used for calculating the power required to heat a mass of material by the dielectric-heating means.

When this formula is applied to an actual high-frequency problem, it should be considered as an approximation, since heat radiation losses and other influencing factors are omitted. These losses are ordinarily less than 20 per cent but in certain applications may be higher. If the problem simply involves the heating of a material a few hundred degrees above room temperature, it is a very useful approximation. If the temperature change involves a change in state of one of the components, such as boiling water or some other solvent, the latent heat of vaporization must be taken into account. The heat energy to convert water to steam (approximately 970 Btu per pound) can be expressed in terms of watt-hours and is approximately 300 watt-hours per pound of water vaporized. The power required can be expressed by

$$W = 300\, M' \text{ watts} \qquad (13)$$

where

M' = pounds of water vaporized per hour

In drying problems, this factor may be much greater than the power required to raise the temperature of the material at the desired rate and, hence, must be added to W obtained in equation 9 to indicate the total power required.

In designing leads and the coupling circuit, it is desirable to know the total current required by the load. This will be given by the equation:

$$I_0 = \sqrt{I_c^2 + I_r^2} \text{ amperes} \qquad (14)$$

where

$$I_c = 2\pi f C_0 e' E \text{ amperes} \qquad (15)$$

$$I_r = I_c \tan\delta \text{ amperes} \qquad (16)$$

FACTORS AFFECTING THE APPLICATION OF DIELECTRIC HEATING

In some applications, all factors in equation 11 or 12 except E and f are known and more or less fixed. In others A and d are subject to some variation by arrangement

Figure 7. Temperature distribution in an iron slab various times after surface temperature is established

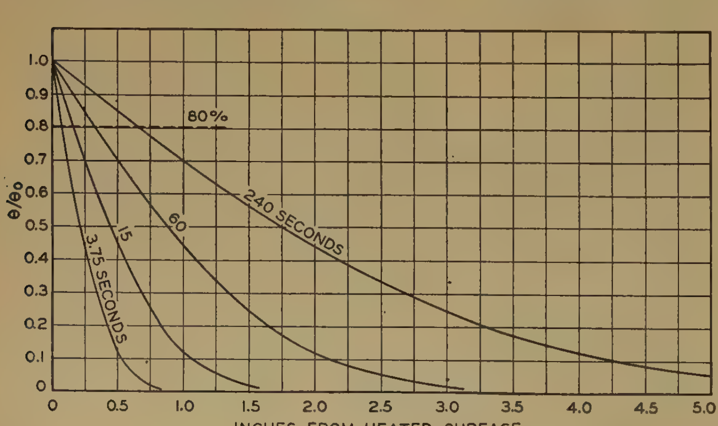

Figure 8. Generator rating versus pounds time degrees rise

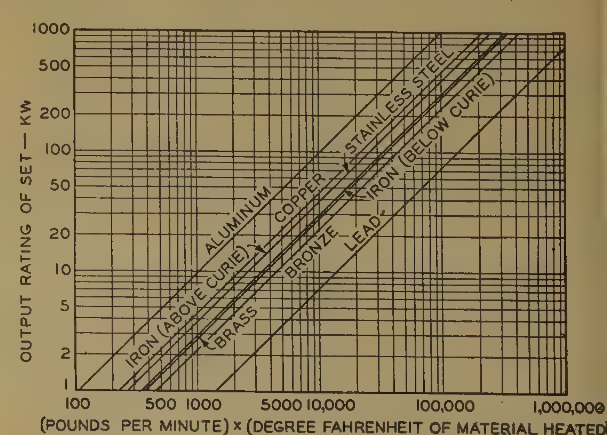

Table II. Approximate Loss Factor and Specific Heat of Several Common Materials

Frequency	Loss Factor e''				Specific Heat
	1 Mc	10 Mc	20 Mc	30 Mc	
Paperboard (soft)		0.024	0.026	0.027	
Paperboard (hard)		0.11	0.12	0.11	0.4
Fiber	0.25				
Porcelain	0.04	0.044	0.06		0.26
Oak dry	0.09				0.40
Birch dry	0.32				
Hard rubber	0.03	0.017	0.017		0.33
Plastics:					
Phenol formaldehyde		0.20 to 0.50			0.30
Urea formaldehyde		0.16 to 0.21			0.40
Cellulose acetate		0.03 to 0.45			0.35
Cellulose nitrate		0.43 to 0.62			

of material or variation of application electrodes.

The loss factor e'' is a property of the material, and can be measured by means of proper equipment. Loss factor of a given material is quite likely to vary appreciably with frequency, temperature, moisture, and so forth; hence measurements must be made over a fair range of the expected variations in the process. A study of loss factor versus frequency sometimes discloses an optimum frequency for heating a particular material. Generally, however, this maximum is quite broad, extending over a range of five or ten megacycles. Table II gives the approximate loss factor and specific heat of a number of common materials.

FREQUENCY LIMITATION

The frequency chosen for a particular application is influenced by several factors, such as the area to be heated, electrode arrangement, practicability of oscillator or generator, design, and power. In order to keep the voltage within reasonable limits the frequency should be as high as practical. However, there are two factors that limit the increase in frequency, namely, voltage distribution and oscillator design.

For a given electrode size, the higher the frequency, the greater the probability of unequal voltage distribution over the area due to the standing-wave effect. Several methods of minimizing this effect are available but some precautions are necessary. If the longest dimension of the electrodes is a small fraction of a wave length, or if the work is scanned, this effect is minimized.

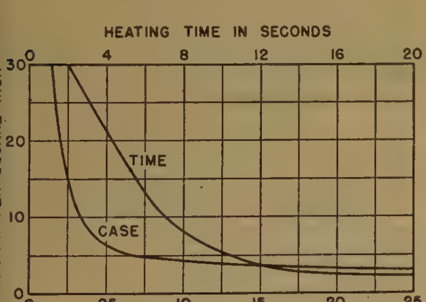

Figure 9. Depth of case versus time and power

Tool steel, 450 kilocycles

Ordinarily if the longest distance from the point of connection to the edge of the high voltage electrode is less than $^1/_{16}$ of a wave length, very little trouble will be experienced. The wave length on a load with a dielectric constant e' is

$$\lambda = \frac{1,000}{f'\sqrt{e'}} \text{ feet} \tag{17}$$

where

f' = frequency (megacycles)

The maximum frequency which can be used without trouble from standing waves (nonuniform heating) is therefore

$$f' = \frac{62.5}{l\sqrt{e'}} \text{ megacycles} \tag{18}$$

l = maximum distance from point of connection to the edge of high-voltage electrode (feet)

Consider a load of plywood with a dielectric constant of 3. The maximum frequency for a load in which l is 5 feet, according to equation 18, will be

$$f'' = \frac{62.5}{5 \times 1.73} = 7.2 \text{ megacycles}$$

The design of electronic generators for high power at high frequencies also presents difficulties.

From a practical viewpoint, at the moment it appears undesirable to use frequencies above 20 megacycles when powers above about 20 kw are involved. Fortunately, satisfactory performance in many applications is obtained with frequencies in the region of 2 to 15 megacycles. This range of frequencies is also satisfactory for the size of electrodes required for most applications.

Figure 10. Removal of rubber from tank treads

The metal is heated by induction to a temperature which frees the bond between the rubber and the metal, thereby facilitating the removal of the rubber. Metal inserts in all types of rubber products can be heated easily by induction

VOLTAGE LIMITATION

From equation 12 it is seen that the power input to a material is proportional to the square of the voltage gradient (E/d). Even at relatively low frequencies (two megacycles) considerable power can be supplied to a load if the voltage gradient is sufficiently increased. Unfortunately, factors arise to limit the voltage which may be applied.

Ordinarily, the voltage across the work should be kept under 15,000 volts. It is not impossible to use voltages above this, but the additional precautions necessary to avoid corona and arc-overs are often more expensive than some other compromise of the engineering factors. The voltage gradient, that is, the voltage per inch permissible across the material, varies widely with the type of material. The radio-frequency voltage which will puncture a given dielectric material, is generally much lower than the 60-cycle voltage which a material will stand. Hence, it is desirable to keep the voltage gradient below 2,000 volts per inch on porous materials, and less than 5,000 volts per inch on the less porous materials, whenever possible.

Two methods are employed to reduce the hazard of voltage breakdown. The voltage may be reduced arbitrarily and the resultant slower heating accepted, or the frequency may be increased, and the factor E^2 reduced in proportion, thus maintaining the desired rate of heating. Frequency cannot be increased indiscriminately because of the frequency limitations discussed earlier. On the other hand, the work may be stacked so that several times

Figure 11. Brazing a metal fillet in a propeller section

Figure 12. Heating a rock bit in a controlled atmosphere to fuse particles of tungsten carbide into the cutting faces and edges

Complete process takes a little over two minutes

the original thickness is obtained, and the possibility of voltage rupture is thereby reduced or eliminated. For a given power input, the rate of heating per piece of work is reduced in proportion to the number of pieces stacked, but the total production will be increased in this same proportion so that the desired production can be obtained with less hazard.

Another type of voltage limitation may be reached in some applications where it is impossible to have the electrodes in contact with the work. This gives rise to a condition in which the space between the electrodes is occupied by two materials of widely different dielectric constants. See Figure 14. The potential distribution may be such in this case as to cause breakdown of the surrounding medium (usually air), resulting in burning of the material to be heated at the point where this failure occurs. The potential distribution may be conveniently calculated by means of the equation:

$$e_1=\frac{E}{1+\dfrac{e_1'd_2}{e_2'd_1}} \qquad (19)$$

where

e_1 = voltage across lower dielectric (material to be heated)

E = total voltage between electrodes

e_1' = dielectric constant of lower dielectric (material to be heated)

e_2' = dielectric constant of upper dielectric (air)

d_1 = thickness of lower dielectric (material to be heated)

d_2 = thickness of upper dielectric (air)

d_1 and d_2 can be expressed in centimeters or inches as long as both are in the same terms.

This should not be construed to mean that air gaps cannot be tolerated in dielectric-heating applications. It is perfectly satisfactory in some cases, when the air gap

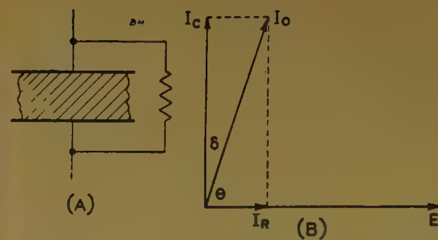

Figure 13. Dielectric heating—equivalent circuit and vector diagram

is not too large compared to the thickness of material to be heated, and the power involved is not too high. The loss factor of air is practically zero, so that little if any electric energy is lost in the air gap, but it does materially increase the voltage which must be applied to the electrodes and, hence, should be avoided if possible.

HEATING IRREGULAR SECTIONS

If the dimension d is uniform throughout the piece (assuming E is uniform and material is homogeneous), uniform heating throughout the area and volume of material between the electrodes is obtained. Note however that if d varies the heat generated per unit of time in any volume varies inversely with the square of the thickness, and uneven heating in the material will result, the thinner sections being heated more rapidly than the thicker sections. For this reason, it is desirable to have the work uniform in thickness and reasonably homogeneous.

There are methods which can be applied to assure uniform heating of certain types of nonuniform sections. If the work is of such a shape that two pieces of work can be placed in complementary positions and the resultant thickness be uniform, the material will heat evenly. For example, two wedge-shaped pieces may be placed together to form a rectangular cross section of uniform thickness. Also the electrodes may be spaced away from the material to be heated at its thinnest section, and be in contact with the material at its thickest point. This method is somewhat critical and if possible should be avoided in a production setup.

HEAT LOSS TO ELECTRODES

It may be found that material adjacent to the electrodes will not reach the desired temperature because of heat conduction to the electrodes. (No heat is generated in these electrodes by the dielectric-heating process.) This heat loss can be reduced by introducing a layer of heat-insulating material between the electrode and the material to be heated. This material will absorb some of the electric energy and, hence, must be included in a complete analysis. Another method would be to heat these outer electrodes by steam or other means to eliminate this heat loss. In this way, uniform heating can be obtained, and the process can be speeded up as well, since losses from the material will

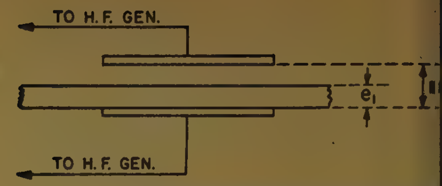

Figure 14. Dielectric heating with air ga

be offset by heat obtained from the heate electrodes.

APPLICATIONS OF DIELECTRIC HEATING I INDUSTRY

Dielectric heating is particularly usef in heating materials of thick section, whic may take several hours to heat by mean of surface heating because of their limite thermal conductivity or to their thick sec tion. Here the factors, economic as well a engineering, favor the application of di electric heating.

The following list of applications in in dustry indicates the wide variety of proc esses in which dielectric heating is bein used or is technically possible. Some o these are in the experimental stage to de termine the economics of the application

Annealing—rayon and nylon treating.
Bonding—plywood, plastics, shatterproo glass.
Chemical processes—catalysis and heating.
Cooking—food and meats.
Curing—rubber and plastics.
Drying—food, wood, ceramics.
Melting—fats.
Softening—plastic preforms and moldin materials.
Spot heating—cementing and gluing of plas tic and wood.
Sterilization—grain and package food prod ucts.

Dielectric heating is easily applied to th heating of articles moving continuously o a belt conveyor between high-voltag plates or electrodes, or between a high voltage electrode and a grounded electrode The articles thus may be heated for dryin (driving off water), curing, or for numer ous other uses.

ECONOMICS OF HIGH-FREQUENCY HEATING

The heat units produced by high-fre quency technique are the same form o energy as obtained from conventiona sources. It can be expressed as Btu o calories as well as watt-hours. The mai difference is in the method of introductio into the material to be heated. Any heat ing process requires a certain amount o useful energy, regardless of the source o this energy. Electric energy in itself is no a cheap source of heat, and additiona losses are encountered in the conversion o conventional-frequency electric energy int electric power of high frequencies. Thi results in a relatively high cost which mus be offset by some advantage not obtainabl by other methods. These advantages ar enumerated later.

The high cost appears in two ways, firs

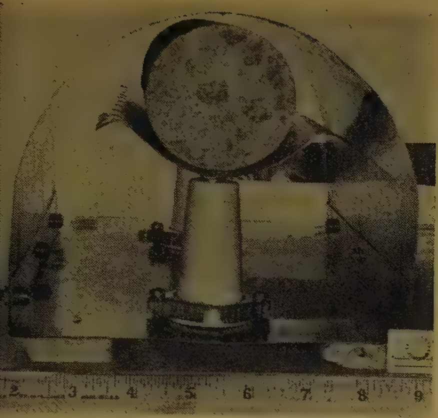

Figure 15. Dielectric heating of plastic preform for a particular molding operation

Reduced molding pressure, improved product quality, and increased production from a press make this application attractive

cost of equipment and cost of operation. To illustrate these factors, two curves are presented. Figure 16 shows the approximate first cost of high-frequency equipment of two types, rotating machine and electronic generators. Considerable spread is indicated for a particular rating because of the variation in accessory equipment such as voltage regulators, application electrodes or coil, necessary for various types of processes. On applications in which frequencies of less than 10,000 cycles can produce the desired rate or depth of heating, rotating machines are quite satisfactory. In fact, the economic picture at present is such that electronic generators are seldom applied at frequencies of less than 100,000 cycles. The cost of high-frequency energy (in terms of kilowatt-hours) as obtained from rotating machines is somewhat lower than that obtained from electronic generators as indicated by Figure 17. (These curves are based on electric energy at one cent per kilowatt-hour, amortization over ten years, average tube replacement, and maintenance.) These costs place electronic equipment at a disadvantage until technical limitations preclude the use of machine frequencies or other sources of heat. The limitations of these more conventional sources of heat, however, permits the use of high-frequency heating to advantage in a wide variety of applications.

High-frequency heating usually succeeds on one or several scores as indicated below:

1. It produces a result not possible by other methods of heating.

2. It increases the speed of a process and saves labor cost.

3. It produces or confines the heating to the part or point where needed, thus reducing the over-all power consumption.

4. It is clean and compact.

5. It reduces rejects, or improves the production quality of a product.

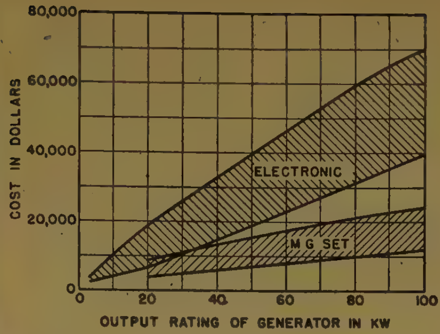

Figure 16. Approximate high-frequency generator costs (including accessories)

6. It is flexible in its application to a variety of operations or processes.

These advantages are often of sufficient importance to make the over-all economics attractive.

SUMMARY

Induction and dielectric heating provides industry with a useful tool. It can produce results not readily achieved by conventional heat sources and has its widest application (because of economics) to problems of this type. It is used successfully in industry today for brazing, soldering, melting, bonding, heat treating, case hardening, curing and many others. The materials involved include iron, steel, brass, copper, plastics, wood, paper, nylon, rayon and other synthetics, rubber, foods, and so forth. New developments will broaden the field and improve the technique of high-frequency heating, but sound judgment and careful study must be employed to assure an economically successful application.

SYMBOL NOMENCLATURE

Although symbols are defined in the text when first used, they are listed as follows for convenient reference.

A = area of material between electrodes (square inches)
$(AT)_c$ = total rms ampere turns in coil
C_0 = capacitance with air dielectric (farads)
C_1 = pitch of coil turns (inches)
C_2 = axial width of coil conductor (inches)
c = specific heat
d = plate separation, thickness of dielectric material heated (inches)
d_1, d_2—see equation 19
E = voltage across dielectric load (rms volts)
e_1 = voltage across lower dielectric rms (see equation 19)
f = frequency (cycles per second)
f' = frequency (megacycles per second)
h = approximate depth of hardening (inches)
I = coil current (rms ampere)
I_c = out-of-phase current in dielectric heating
I_r = inphase current in dielectric heating
I_0 = total current in dielectric heating
I_w = current in material heated inductively

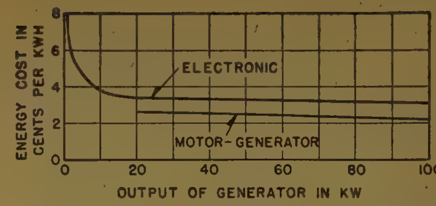

Figure 17. Approximate cost of high-frequency energy (including tube replacement, maintenance, amortization, and power)

K = constant (see equation 9)
l—see equation 18
l_c = axial length of coil (inches)
M = pounds of material heated
N = turns per inch in coil
p = average length of current path (inches)
p' = outer periphery of work (inches)
R_w = resistance of the work (ohms)
T = temperature rise (degrees centigrade)
t = time (seconds)
t' = time (minutes)
W = total power input (watts or kilowatts)
ϵ' = dielectric constant
ϵ_1', ϵ_2'—see equation 19
$\epsilon'' = \epsilon' \tan \delta$ = loss factor
δ = effective depth of current penetration (inches)
λ = wave length (feet)
$\tan \delta$ = tangent of loss angle in dielectric heating
ρ = electrical resistivity (ohm-inches) (ohm-inches = ohm-cms/2.54)

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Aviation and the Electrical Engineer

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Rapid advances in aviation have created a whole series of new problems for electrical engineers and aviation designers. The electrical and aviation industries must work together to develop satisfactory aircraft electric equipment, standardize minimum requirements for such equipment, and educate members of both industries to comply with these standards.

EVERYONE is familiar with widely publicized advertising in recent periodicals which states that an airplane can go from the local airport to any other airport in the world in 60 hours. For many this is dramatic notification of the possibilities in aviation.

Engineers who work with aviation are brought face to face with a whole series of new problems as a result of this ability to reach any place in $2^1/_2$ days. At the same time these engineers must accept a new and more comprehensive responsibility. Designing equipment for an airplane is not like designing equipment for industry, the automobile, or the household. Further, the operator of an airplane cannot afford to have a device quit in flight, as results may be disastrous.

WEIGHT A PROBLEM IN AIRPLANE

One of these problems is weight. A pound saved in a commercial transport airplane is worth its weight in gold. In a military airplane each pound saved means that three additional rounds of 50-caliber ammunition can be carried. Any one of these three rounds might make the difference between a safe return to base and no return at all. The aviation engineer considers anything and everything as being too heavy. He is continually striving to eliminate ounces—which in turn mean pounds—from the completed airplane.

The electrical engineer too often is unconcerned about weight, since he is several steps away from the aircraft designer who has primary responsibility for weight.

Weight is so important to the aviation designer that he will sacrifice efficiency and some measure of reliability to attain a minimum weight. This is contrary to the tenets of the electrical engineer who is skilled in the more conventional lines of electrical design.

The performance of the airplane depends on weight. The ability of the airplane to clear the field on take-off; its ability to climb; its high speed, range, and service ceiling; and its landing speed are all dependent on weight. It is little wonder that the aeronautical engineer consistently endeavors to eliminate every unnecessary ounce.

The normal fighter airplane can be divided into weight groups as follows:

Aircraft structure	40 per cent
Equipment	40 per cent
Pay load	20 per cent

Every fraction of weight that can be eliminated from the 40 per cent equipment can be added to the 20 per cent for pay load. In the fighter airplane this means more gasoline and consequently more range, or it means more ammunition and therefore more fire power. M. Boe, in an article for *Aero Digest* which was subsequently reproduced in a British magazine, *Flight*, has stated that the weight of instruments and small accessories produced by the Germans was 10 to 15 per cent lighter than their corresponding American counterpart. This apparently small difference in the weight of each accessory provides for a great deal of gasoline or armament.

SUPPORTING STRUCTURE A FACTOR

Another factor which cannot be neglected is that each pound of equipment which is added to the air frame requires approximately one-half pound of structure to mount and support that piece of equipment. If eight per cent can be saved in the weight of equipment, a fighter airplane having a gross weight of 7,250 pounds can increase its range by 25 per cent, or it can increase its fire power by 750 rounds of 50-caliber ammunition, or 17 square feet of armor plate can be added. The eight per cent saving may be the means of bringing its own airplane home or of protecting a bomber for a longer range. According to Mr. Boe, a weight reduction of $3^1/_2$ per cent in the total airplane would increase the ceiling by 3,000 feet. All of these ounces which are saved in individual items of equipment can add up to a sufficient margin to be the margin of victory.

It is inevitable that these efforts to decrease weight will result in an increase in cost. However, it must be remembered that military airplanes cost five to ten dollars per pound, that commercial transports cost three to four dollars per pound, and that sport airplanes cost two to three dollars per pound. There are special instances of much higher prices. It is plainly evident that a different sort of thinking is needed for this type of vehicle as compared to the automobile which costs 30 cents per pound.

INCREASE IN COST JUSTIFIED

A higher cost is justified, because the return on the investment is correspondingly higher. A pound has a potential value of more than $200 per year to the air lines, but as yet the useful life of an airplane is not known. Most transport airplanes in use today are more than five years old, indicating that the pounds saved have a potential value of $1,000. In the military airplane a pound represents three to four rounds of 50-caliber ammunition. Any one of those rounds may be the one which makes it possible for the airplane to return home safely.

The relation of weight to airplane performance can be described by the following information:

(*a*). Maximum speed .... $V_m \alpha \sqrt{W}$

(*b*). Landing speed .... $V_e \alpha \sqrt{W}$

(*c*). Rate of climb .... $V_c \alpha 1/W$

(*d*). Service ceiling .... $A \alpha 1/W$

(*e*). Range of the airplane ..... $L \alpha \dfrac{W}{W\ \text{empty}}$

As the size of airplane increases, the amount of fuel which must be carried increases in proportion. It is in these types of aircraft that the efficiency of equipment items becomes important. An engine will consume 0.4 to 0.5 pound of fuel per horsepower per hour of operation. The better generators which are mounted on this engine have an efficiency of 70 to 80 per cent at their usual load. The loss of power in the wiring is limited to approximately three per cent. Motors will have an efficiency of 50 to 80 per cent, depending on size and design.

If one takes as an example an over-all efficiency of 50 per cent for a motor and its generator, a one-horsepower motor will be responsible for a fuel consumption of one pound per hour. Operating at reasonable speeds, this motor may have a fixed weight of eight pounds. The maximum range of DC-3 transports now used on commercial air lines is about eight hours. In such an airplane, the motor which weighs eight pounds would consume eight pounds of fuel making a total weight of 16 pounds. It is possible to build airplanes having a range much higher than eight hours, and in fact such are already in use for trans-

Essential substance of an address given before the AIEE summer technical meeting, St. Louis, Mo., June 27, 1944, and before the AIEE Los Angeles technical meeting, Los Angeles, Calif., August 30, 1944.

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oceanic service. If the range is 20 hours, then the fuel consumed by the motor is 20 pounds, and this is much higher than the fixed weight of eight pounds. If by increasing the fixed weight of the motor to 8.5 pounds the weight of fuel consumed can be reduced to 18 pounds, a worthwhile saving has been made.

This type of argument does not apply to intermittently operated motors. In this type of motor it is desirable to strive for the minimum fixed weight at a sacrifice in efficiency. A motor which is used for only a few seconds in a long flight must have a minimum of weight. The worst example of this sort is the engine starter. This motor is used for only a few seconds, and more important it is used only on the ground. This type of equipment should weigh as close to 0 pounds as the designer can make it.

Similarly, space is an important problem. Most aircraft devices are too big to suit the aerodynamicist. Large devices require much space, and this means a bigger fuselage or a thicker wing. In either event the power required is increased, and the performance of the airplane is reduced. Perhaps it is fortunate that most accessory manufacturers will find themselves faced with the problem of designing a piece of equipment to fit in the available space. This means that the designers of the engine and structure have the first opportunity to restrict space, and, while the result may be arbitrary, the accessory manufacturer must live with that decision.

RELIABILITY ESSENTIAL IN AIRCRAFT

A problem which faces every designer is that of reliability. Reliability is essential in aircraft. While a satisfactory life of equipment without attention is much shorter for aircraft devices than it is for industrial devices, it is still a serious design problem. If an electrical device can be depended upon for continuous operation for more than 1,000 hours without any attention and for a life of 5,000 hours with some attention, it normally will be satisfactory. Every effort must be made to avoid nuisance failures, as these can alter transport schedules and can cause an aborted mission in military aircraft. For example, pilots of air-line transports habitually check their landing lights prior to take-off. If a lamp fails during this check, the airplane must be brought back to the hangar and relamped.

Half the problem of obtaining reliability is answered by proper system protection. Continuity of service is just as important to the aircraft electric system as it is to the public utility. In fact, a multigenerator installation in aircraft has many of the same problems as a multistation network.

Protection can be divided in four parts:

1. Generator-relay backup protection.
2. Bus and feeder network protection.
3. Circuit protection.
4. Equipment protection.

The generator normally is protected by a reverse-current relay, but a backup device is needed for the rare instances when a relay may weld. This is important in a dual-generator installation, since the entire output of one generator can be absorbed through a defective relay if the other generator is out of action. The backup device should be polarized to pass any amount of current in a forward direction, and it should have such current–time characteristics that it does not function until the reverse-current relay has had every opportunity to operate.

Bus and feeder networks should be so designed that accidental grounds and combat damage will interfere with a minimum section of the supply network. While open wiring has exceptional facility for clearing itself of damage, no efforts should be spared to make the system even better. Channeled feeder circuits with sectionalizing protective devices represent the ultimate in network protection.

The device which protects circuits should protect only the wiring and not the equipment load. This may be a fuse or circuit breaker, although the latter has a tremendous advantage when the supply problem is being considered. Since the device protects wiring, its current–time response should be proportional to those characteristics of conductors in the worst ambient temperature.

INTEGRAL PROTECTION IMPORTANT

Equipment must be protected integrally. For example a radio receiver using smaller conductors within than that of the power-supply line should be internally protected by a fuse, circuit breaker, or other device. Motors are the weakest link in the electric system. They fail quickly under overload or stalled operation. They must have integral protection against burn-out with the resultant problem of replacement.

The second half of providing reliability is to design equipment so that it can be operated in any environment.

These operating conditions under which an airplane must function bring a whole set of new problems. There are eight of these as follows:

1. Altitude.
2. High temperature.
3. Low temperature
4. Vibration.
5. Sand.
6. Salt.
7. Humidity.
8. Radio noise.

Aircraft designers are dreaming of the day when airplanes will be able to fly at altitudes of nine or ten miles. This means that electric-equipment manufacturers must anticipate this probable operating condition. It is well known that the atmosphere is very cold at such altitudes, but not withstanding this fact it is difficult to cool electric apparatus properly. This is due to the fact that the density of the air decreases faster than the temperature. At 18,000 feet the air is one-half sea-level density; at 36,000 feet it is one-fourth. At the same time the low temperature combined with low density removes practically all the moisture from the atmosphere. Because of the increased activity of gamma ions and other causes, the ionization potential is a small fraction of its sea-level value, and this increases the likelihood of insulation breakdown. The problem of insulating electric circuits at these high altitudes is approximately four times as severe as it is at sea level. It is essential that electric apparatus be designed for excellent commutation as arcing cannot be tolerated. Arcing which might be considered minor at sea level can become a continuous flame at high altitudes.

OPERATION AT EXTREME TEMPERATURE

It is unwise to ignore high temperatures. While the temperatures within the temperate zone of the continental United States are quite reasonable, it must be remembered that an airplane can be at the hottest place in the world within 60 hours. This leaves no opportunity for changing of the equipment to accommodate the coming atmospheric conditions. For this reason, it is common practice to design equipment to withstand operating temperatures of plus 165 degrees Fahrenheit. This is based on ambient temperature of approximately 130 degrees Fahrenheit with some addition for the increase of temperature within the airplane due to accumulated heat.

The aforementioned temperature can occur on the ground. It is common practice to operate the engine compartment at 140 degrees Fahrenheit at all altitudes. This high operating temperature combined with the low density of the atmosphere already mentioned makes a still more difficult cooling problem. It is quite likely that this operating temperature will increase to still higher levels such as 250 degrees Fahrenheit.

At the other extreme, minus 65 degrees Fahrenheit often can be encountered on the ground in the arctic regions. This is the common design requirement for ground operation. However, it is known that at high altitudes above the tropic zones temperatures as low as minus 110 degrees Fahrenheit can be encountered. At first glance this would not seem to be serious, since the equipment normally will be operating and will be warm. However, spare equipment often is called upon for service at these temperatures and must be able to function. Likewise, if a rapid descent is made from such altitudes, many pieces of equipment which normally are used for landing will be called upon to function before they are warmed to operating temperature.

For many years a vibration-frequency range of 10 to 55 cycles per second has

been the standard test for aircraft equipment. This is inadequate. Many failures of engine-driven accessories have occurred at vibration frequencies of nearly 200 cycles per second. Harmonic frequencies to 500 cycles per second can be expected. The electrical designer must assume that the product is going to be operated at the critical frequency and must function satisfactorily and continuously when so operated.

Sand and dirt have caused more failures of electric apparatus by clogging relays, magnetic contactors, and bearings than any one would guess. For this reason it is now common practice to require that all relays be sealed against sand, dirt, and atmosphere. This sealing of the relays eliminates not only sand and dirt but also moisture and salt. It permits satisfactory operation at altitude, and it may permit an increase in the rating of a given size.

Atmosphere containing salt eventually will cause any poorly designed piece of electric apparatus to fail. When the airplane is operated in tropical climates, this salt will work its way into all parts of the apparatus and will cause a short circuit across the surface of insulation. In addition, it hastens the corrosion of exposed parts. The Navy Department has faced this problem for many years, and many of their practices have been lifted bodily by the aviation industry to combat this problem.

Humidity alone will cause early failure of any type of electric apparatus unless proper precautions are taken. These failures are due to rust and corrosion in metal parts and to fungus growth in cloth and leather goods.

Tests of humidity alone concern only moisture. Electric equipment also should withstand leakage of lubricating and hydraulic oils, gasoline, cleaning fluids, and other chemical agents used by the aeronautical industry.

ELIMINATE RADIO NOISE

Most electrical engineers realize that the current war is a radio war. This means that electric apparatus must not cause interference with the proper performance of radio equipment. The electrical engineer must assume this responsibility at the outset and make proper precautions in the original design so that unnecessary radio noise is not propagated through space or along the conductors.

In conclusion, while it can be stated that the problems facing the average electrical engineer are difficult, it also can be said that he must meet these problems. The electrical industry cannot ask the aviation industry to use electric equipment unless that equipment equals all other types in all respects and excels it in some. Accordingly, the problem in general includes not only the development of satisfactory equipment, but also the conduction of a program to educate aeronautical engineers in the proper application of this equipment. It is essential that professional and industrial groups work together on this program. An immediate task is suggested as follows:

1. Determine operating conditions.
2. Standardize minimum requirements for aircraft electric equipment.
3. Define adequate tests for insuring compliance with these standards.
4. Educate industry members or otherwise enforce compliance with these standards.

Rectifiers and Inductive Co-ordination

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NOISE induced from power-supply circuits into circuits used for transmission of speech or music is caused by the harmonic-frequency voltages and currents present in the power-system wave shape.[1] The interfering effect of a foreign voltage on a telephone circuit depends on its frequency, increasing with frequency up to a certain value and then decreasing. The voltage induced in a telephone circuit by a given voltage or current on a power-supply circuit also depends on the frequency, the mutual relation or coupling being directly proportional to frequency. When the effect of harmonics present on the power circuits is considered, it is necessary to give due weight to both factors. The term "inductive influence" is used in discussing them. The inductive influence of a power-system voltage or current wave shape is measured in terms of "telephone influence factor,"[2] abbreviated "TIF", which factor takes into account the variation of both the interfering effect and coupling with frequency. Figure 1 shows two TIF curves, one designated 1935 and the other tentative 1941.[2] The shape of the curve depends, of necessity, on the characteristics of the telephone instruments in use, and the change from the 1935 to the 1941 curve reflects the improvements that have been made in telephone instruments. The 1941 curve is just coming into use now, and the majority of the investigations made in recent years have been based on the 1935 curve.

The co-ordination problem introduced by mercury-arc rectifiers appears on both the d-c and the a-c circuits connected to them. The d-c problem was the first one to be encountered. Incidentally, one of the early rectifier problems was encountered in Montreal, and the control measures applied on that installation still are generally used. This article, which discusses effects on both the d-c and a-c systems, applies specifically to polyphase rectifiers of the common mercury-cathode type. It also applies in general to single-anode rectifiers of the mercury-cathode type operating in either glass bulbs or metal tanks.

EFFECTS ON D-C SYSTEMS

The common-cathode mercury-arc rectifier is usually built with 6 or 12 phases. Figure 2A is a schematic diagram of one of the common methods of operating a six-phase rectifier. Figure 2B shows the wave shape of the direct voltage at no load, and Figure 2C shows it under load. The voltage consists of a d-c component with a superimposed ripple. The ripple can be analyzed into a series of harmonic frequencies. Table I shows the harmonic voltages for a 60-cycle system expressed as percentages of the average direct voltage.[3] Only a limited number of measurements under load are represented, and values outside this range may be expected.

With a higher number of phases the harmonic frequencies are correspondingly higher; for example, in an ideal 12-phase installation the harmonic frequencies are 720 cycles and its multiples. In practice it is found that all the harmonics present with a six-phase group are present also with a higher number of phases, but those of 360 cycles, 1,080 cycles, and so forth, are reduced in magnitude, the reduction depending on the characteristics of the installation.

Filtering has proved to be the most gen-

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A paper presented at a joint meeting of the AIEE Montreal Section and the Montreal branch of the Engineering Institute of Canada, December 16, 1943. The diagrams have been drawn from previously published material as indicated by text references where they are discussed.

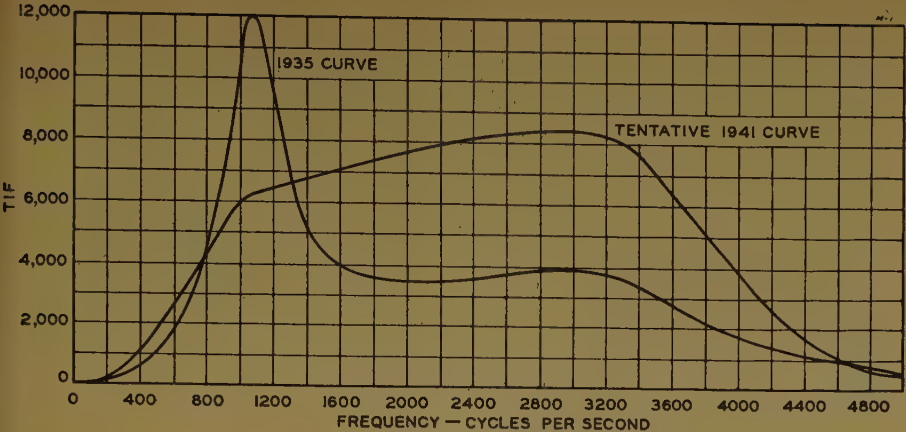
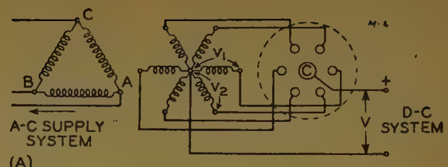
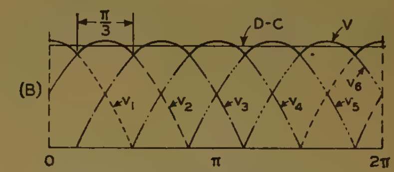


Figure 1. Comparison between TIF weighting curve adopted in 1935 and curve adopted tentatively in 1941, reflecting the improvements made in telephone instruments

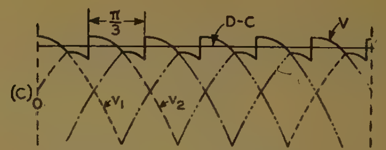
The tentative 1941 weighting curve is based on FIA line weighting as given in engineering report 45 of the Joint Subcommittee on Development and Research of the Edison Electric Institute and Bell Telephone System. Scale based on 1,000-cycle TIF of 6,000



Schematic circuit diagram



Output-voltage wave shape at no load



Output-voltage wave shape under load

Figure 2. Schematic diagram and output-voltage wave shapes of six-phase mercury-arc rectifier

erally satisfactory method of controlling the harmonics impressed on the d-c system.[4] Figure 3 is a schematic diagram showing a common arrangement of the equipment. It consists of an inductive reactor in series with the circuit and a number of tuned shunts connected across the system on the load side of the reactor. A tuned shunt is required for each of the harmonics that is to be suppressed. The usual experience is that if shunts are provided for three or four frequencies, they will also reduce to some extent all the higher-frequency harmonics present. The design of the filtering equipment depends of course on the characteristics of the particular case. It is generally quite practicable to make the equipment such that the voltage TIF on the d-c system is comparable to the values found on systems supplied by rotating machines.

The problem of co-ordination with the d-c system arises usually only where rectifiers are used to supply traction circuits, either street railways or other electrified railways. In most other cases the d-c circuits are confined to the immediate vicinity of the load and are short, and it is possible to avoid communication-circuit exposures to them.

EFFECTS ON A-C SYSTEMS

It is a characteristic of a mercury-arc rectifier that harmonics are present in the load current taken from the a-c circuit even though they are not present in the generated voltage applied to the supply system.[5,6,7] To assist in obtaining some idea of what happens, consider an ideal case in which the alternating voltage is a pure sine wave and the impedance of the a-c supply circuit and of the rectifier transformer are negligibly low. In Figure 4A the wave form I_A shows the current in one phase of the three-phase circuit supplying a six-phase rectifier.[9] Wave form I_B is the same quantity for a six-phase rectifier with a different connection of the primary windings of the rectifier transformer. One primary connection is star and the other delta. The wave shapes depart markedly from a sine wave.

Analysis of the wave shape of I_A or I_B shows that it consists of a series of harmonics represented by $ps \pm 1$ where p is the number of phases and s is any whole number.[9] For a six-phase rectifier the frequencies are the odd nontriple harmonics, and for a 60-cycle system they are 300 and 420 cycles, 660 and 780, 1,020 and 1,140, and so forth. In the theoretical square wave the magnitude of the nth harmonic is $1/n$ times the magnitude of the fundamental-frequency current. The currents are identical in each phase of the three-phase supply circuit so the harmonics introduced are balanced components.

The distortion of the voltage wave shape depends on the impedance at harmonic frequencies looking back into the power system. A simplified view of what occurs may be obtained by considering the rectifier as a generator of high internal impedance which feeds back into the power-supply system. Figure 5 is a schematic diagram which demonstrates the action.[6] The harmonic voltage E_n produced by the rectifier acts on a circuit consisting of the internal resistance of the rectifier R_0 in series with Z_{tn}, the impedance of the rectifier transformer, and Z_{sn}, the impedance looking back into the supply system. Since the rectifier load is a balanced three-phase load and the effects are alike for each phase, the diagram shows the circuit for only one phase to neutral.

The increasing use of large mercury-arc rectifiers during recent years has introduced new inductive co-ordination problems between electric power-supply and communication lines, and the probable expansion in the use of this equipment in the postwar years is expected to intensify these problems. The subject has been treated at length in previous technical papers and publications, some of which are listed in the references; this article reviews the over-all problem and discusses its more important aspects.

Examination of the diagram helps in understanding the following conclusions that have been reached as a result of measurements on rectifier installations:

1. The harmonic currents increase with increasing load on the rectifiers. This corresponds to a reduction of R_0, the rectifier internal resistance, as the load increases.

2. For a particular rectifier, the harmonic currents depend on the total impedance in the circuit, namely, on the rectifier load and the impedances of the rectifier transformer and of the supply system.

3. The harmonic voltages appearing on the supply system depend on the harmonic currents flowing and also on the system impedance Z_{sn}. The voltage is directly proportional to Z_{sn} for a particular value of current. Any arrangement of the power system that reduces the impedance looking back into it from the rectifier will usually reduce the voltage-wave-shape distortion. Conversely, an increase in the system impedance will increase the effects.

4. The larger the rating of the rectifier, the lower will be its internal resistance and the impedances of the rectifier transformer and supply system. Hence the harmonic currents increase with the load rating of the rectifier.

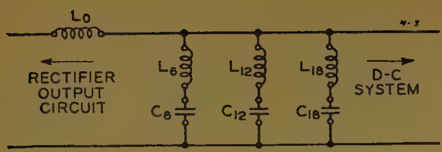


Figure 3. Schematic diagram of filter for six-phase mercury-arc rectifier

Relations between shunt constants for 60-cycle supply system:

$$2\pi(360)L_6 = \frac{1}{2\pi(360)C_6}$$

$$2\pi(720)L_{12} = \frac{1}{2\pi(720)C_{12}}$$

$$2\pi(1{,}080)L_{18} = \frac{1}{2\pi(1{,}080)C_{18}}$$

The harmonic voltage E_n produced by the rectifier depends on a number of factors. An important one is the amount of phase control used to vary the direct voltage and the load taken by the rectifier. For small values of phase control the change is not great, but for values beyond a few per cent the harmonic currents increase rapidly with increasing phase control. There is also evidence that the wave-shape distortion depends on the nature of the d-c load supplied by the rectifier.

MULTIPHASE OPERATION[8,9]

In the early investigations of the effects of rectifiers on a-c power-system wave shape, it was found that the distortion was less for 12-phase operation than for six-phase. Figure 4A shows two six-phase rectifiers arranged for 12-phase operation by using a star-connected primary for one of the rectifier transformers and a delta-connected primary for the other.[9] As mentioned previously, wave forms I_A and I_B show the wave shape of the currents in one phase of the three-phase circuit supplying each six-phase rectifier. Wave form I_C shows the wave shape of the current to the 12-phase group (vector sum of I_A and I_B), which approaches a sine wave more closely than either I_A or I_B.

In a polyphase rectifier each anode fires once during each cycle of the applied voltage. The anodes are arranged symmetrically so that the time intervals between the firing of successive anodes are equal. For a rectifier with p phases, the phase interval between anodes which fire successively is $360/p$ degrees.

In a six-phase rectifier the phase interval between the firing of successive anodes is 60 degrees and in a 12-phase rectifier it is 30 degrees. If a number of six-phase units are associated in such a manner that the phase interval between the firing of successive anodes is decreased, it is equivalent to increasing the number of phases. For example, 15 degrees between successive anodes corresponds to 24-phase operation, 12 degrees to 30-phase operation, 10 degrees to 36-phase operation, and so on.

For ideal conditions the harmonics produced in the a-c system would be the series $ps \pm 1$ where p is the equivalent number of phases and s is any whole number. For 30-phase operation the lowest harmonics would be the 29th and 31st, corresponding to frequencies of 1,740 and 1,860 cycles on a 60-cycle system. Table II shows for such theoretical conditions the harmonics that would be present on a 60-cycle system for different numbers of recifier phases.[9] On a 25-cycle system the harmonics and the percentages would be the same but the frequencies would be lower in proportion to the fundamental frequency. In practice the harmonics that are shown as suppressed are only partially suppressed, the amount depending on the characteristics of the installation and the manner in which the rectifiers are operated.

A number of methods may be used for obtaining multiphase operation. In general the individual rectifiers, if multianode, or groups of rectifiers if single-anode units are used, are six-phase. Two common methods of obtaining 12-phase operation are shown in Figure 4.[9] Figure 4A shows the use of star and delta primary connections on the rectifier transformers to obtain 30-degree phase displacement. Figure 4B shows the use of two sets of six-phase zigzag secondary windings on the rectifier transformer. The zigzag connection provides a 15-degree phase displacement; one set of windings is connected to advance the anode voltages 15 degrees while the other set retards 15 degrees, thereby providing a 30-degree displacement between the two sets.

Phase displacement in three-phase circuits may be made readily by means of phase-shifting transformers as shown schematically in Figure 6.[8,9] The vector diagram indicates how the secondary voltages are shifted with respect to the primary voltages. The transformer can be designed to provide phase shift of any value up to 120 degrees. By interchanging the supply and load connections, the phase shift can be made either plus or minus.

Figure 7 shows two methods of using phase-shifting transformers to obtain 36-phase operation with six six-phase units.[9] The first method employs phase-shifting transformers to do all the phase-shifting. All the rectifier transformers are alike. It may be noted that as much as +25 degrees is required in one phase-shifting transformer and −25 degrees in another. The second method employs phase-shifting transformers in association with delta and star primary connections on the rectifier transformers. In this way it is possible to limit to 10 degrees the maximum shift to be provided by phase-shifting transformers.

It was stated hereinbefore that the har-

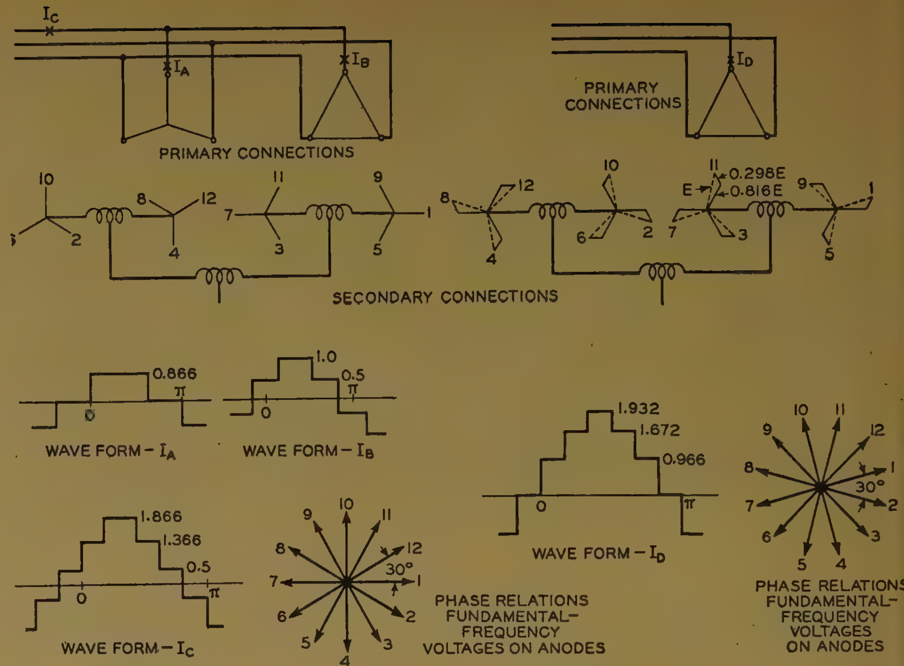


Figure 4. Schematic diagrams and wave forms for two 12-phase rectifier arrangements

A (*left*). *Primary windings of rectifier transformer connected wye, delta; secondary, quadruple wye*
B (*right*). *Primary windings of rectifier transformer connected delta; secondary, quadruple zigzag*

Table I. Harmonic Voltages in D-C Output of Six-Phase 60-Cycle Rectifier

Order of Harmonic	Frequency of Harmonic (Cycles Per Second)	Percentage Ratio of Effective Harmonic Voltage to Average Direct Voltage: No Load (Theoretical)	Measured Under Load
6	360	4.04	4.5 –5.95
12	720	0.98	1.26–1.37
18	1,080	0.44	0.53–0.90
24	1,440	0.25	0.61–0.72
30	1,800	0.16	0.40–0.80
36	2,160	0.11	0.43–0.62
42	2,520	0.08	0.41–0.44
48	2,880	0.06	0.35–0.36

monics which are shown as suppressed with ideal multiphase operation are only partially suppressed in an actual case. To obtain maximum suppression, the following requirements should be observed:

1. All units comprising the multiphase group should be identical and should carry the same load. If phase control is used, it should be substantially the same for all units.

2. The impedance of the rectifier transformer plus that of the phase-shifting transformers, if used, should be identical for each six- or 12-phase unit. If phase shifting transformers are not needed for some of the units, inductive reactors of equal impedance may need to be substituted.

3. The phase-shifting transformers or other devices used should provide exactly the phase displacement required. Even a small departure at the fundamental frequency will be large when referred to the higher harmonic frequencies.

In some installations suppression ratios as high as 80 to 1 have been obtained for the harmonics below about the 19th. For the higher frequencies it is not possible to do so well, ratios of the order of 5 to 1 being more common.

If one or more six-phase units of a multiphase group are shut down, balanced multiphase operation no longer is obtained. The magnitude of the effects on power-system wave shape may be deduced by looking at the condition as follows. Assume a perfectly balanced multiphase group of p phases in which all harmonics below $p \pm 1$ are suppressed. If one six-phase unit is shut down, the harmonics appearing on the system apart from the $p \pm 1$ harmonics correspond to those that would exist if this six-phase unit were operating alone and carrying its normal load.

As the number of phases in a multiphase group is increased, the benefits obtained are limited by the foregoing factors. With a large number of units, it is more difficult to maintain all the conditions required to obtain the results that are theoretically possible.

CHARACTERISTICS OF POWER-SUPPLY SYSTEMS

Considerable attention has been given to the manner in which the characteristics of the rectifiers affect the magnitude of the harmonics produced. The characteristics of the power system are also important in determining the wave-shape distortion, particularly at a distance from the rectifier load. The impedances of power equipment such as generators and transformers increase proportionally to frequency and are largely inductive reactances over the frequency range of interest. The impedances presented by transmission lines may be either inductive or capacitative reactances and may vary from one to the other over the frequency range. Therefore, if the power-supply system is extensive the impedance looking back into it from the rectifier will be a very complex function of frequency.[10] The wave-shape distortion a rectifier would cause in these circumstances would differ markedly from what it would be if the system impedance were uniform over the frequency range or varied in a simple manner with frequency.

OTHER CONTROL MEASURES

Other means of controlling the wave-shape distortion are feasible in certain situations. If exposures of communication circuits exist only in some parts of the power system, it may be possible to operate the system in such a manner that the wave-shape distortion does not extend to that part or is reduced to such an extent

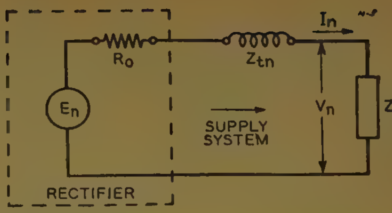


Figure 5. Schematic diagram of circuit on which rectifier harmonic voltages are impressed (phase-to-neutral equivalent circuit)

E_n—Harmonic voltage produced by the rectifier
R_0—Rectifier internal resistance
n—Order of harmonic
Z_{tn}—Rectifier-transformer reactance at the nth harmonic
Z_{sn}—Phase-to-neutral system impedance external to the rectifier transformer at the nth harmonic
V_n—Harmonic phase-to-neutral line voltage due to the rectifier
I_n—Harmonic line current due to the rectifier

that it is no longer troublesome. Usually there are disadvantages to following a plan that impairs the flexibility of the power system, and this means may not be looked upon with favor as a permanent solution. It may be very helpful, however, in the interval pending the application of permanent measures.

In some situations the use of frequency-selective devices or filters in the power-supply system is the best solution. Such devices may be shunt capacitors, series inductive reactors, or any combination of such items. With well-balanced multiphase operation the lowest unsuppressed harmonics are sometimes the chief components of the TIF. Selective devices for these two frequencies will improve the wave shape greatly without being unduly costly.

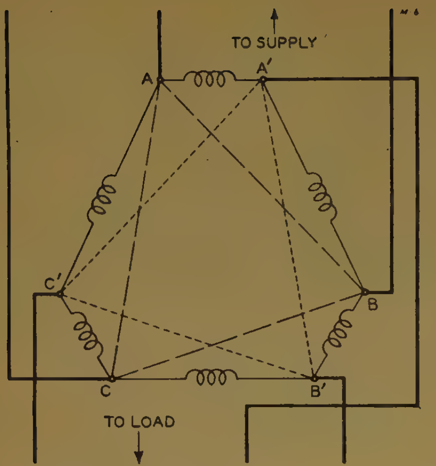
Sometimes the characteristics of the power system are such that resonance occurs at a harmonic frequency and the magnitude of that harmonic is increased out of proportion to the others. Filters to suppress the one frequency will make marked improvement. A factor to be considered with filters is that in some instances they may be associated with the part of the power system where they are needed, and hence their current and voltage rating usually will be lower than would be required if they were installed at the rectifier.

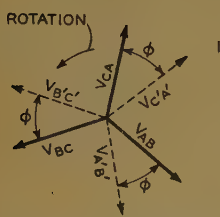
CO-OPERATIVE ACTION NEEDED

Many rectifier installations do not introduce co-ordination problems. However, when problems do arise they may be serious and widespread. The effects may be manifest over a large part of a power network or they may appear in any part of it. In some cases they appear in remote parts of the system without causing trouble in the vicinity of the rectifier. If the equipment is already operating, co-ordinative measures are apt to be costly and difficult to install, and communication services will be adversely affected in the meantime.

Table II. Relation Between Harmonics in Theoretical Supply-Circuit Current and Number of Rectifier Phases—60-Cycle System

Order of Harmonic	Frequency (Cycles Per Second)	Harmonic Currents in Per Cent of Fundamental for the Following Numbers of Rectifier Phases								
		6	12	18	24	30	36	48	60	72
5	300	20.0	0	0	0	0	0	0	0	0
7	420	14.3	0	0	0	0	0	0	0	0
11	660	9.09	9.09	0	0	0	0	0	0	0
13	780	7.69	7.69	0	0	0	0	0	0	0
17	1,020	5.88	0	5.88	0	0	0	0	0	0
19	1,140	5.26	0	5.26	0	0	0	0	0	0
23	1,380	4.35	4.35	0	4.35	0	0	0	0	0
25	1,500	4.00	4.00	0	4.00	0	0	0	0	0
29	1,740	3.45	0	0	0	3.45	0	0	0	0
31	1,860	3.23	0	0	0	3.23	0	0	0	0
35	2,100	2.86	2.86	2.86	0	0	2.86	0	0	0
37	2,220	2.70	2.70	2.70	0	0	2.70	0	0	0
41	2,460	2.44	0	0	0	0	0	0	0	0
43	2,580	2.33	0	0	0	0	0	0	0	0
47	2,820	2.13	2.13	0	2.13	0	0	2.13	0	0
49	2,940	2.04	2.04	0	2.04	0	0	2.04	0	0
53	3,180	1.89	0	1.89	0	0	0	0	0	0
55	3,300	1.82	0	1.82	0	0	0	0	0	0
59	3,540	1.70	1.70	0	0	1.70	0	0	1.70	0
61	3,660	1.64	1.64	0	0	1.64	0	0	1.64	0
65	3,900	1.54	0	0	0	0	0	0	0	0
67	4,020	1.49	0	0	0	0	0	0	0	0
71	4,260	1.41	1.41	1.41	1.41	0	1.41	0	0	1.41
73	4,380	1.37	1.37	1.37	1.37	0	1.37	0	0	1.37
Current TIF		1,060	515	913	318	183	140	116	65	26





V_{AB}, V_{BC}, V_{CA}—*Supply line voltages*

$V_{A'B'}$, $V_{B'C'}$, $V_{C'A'}$—*Load voltages*

ϕ—*Angle of phase shift*

Figure 6. Schematic and vector diagrams for phase-shifting transformer

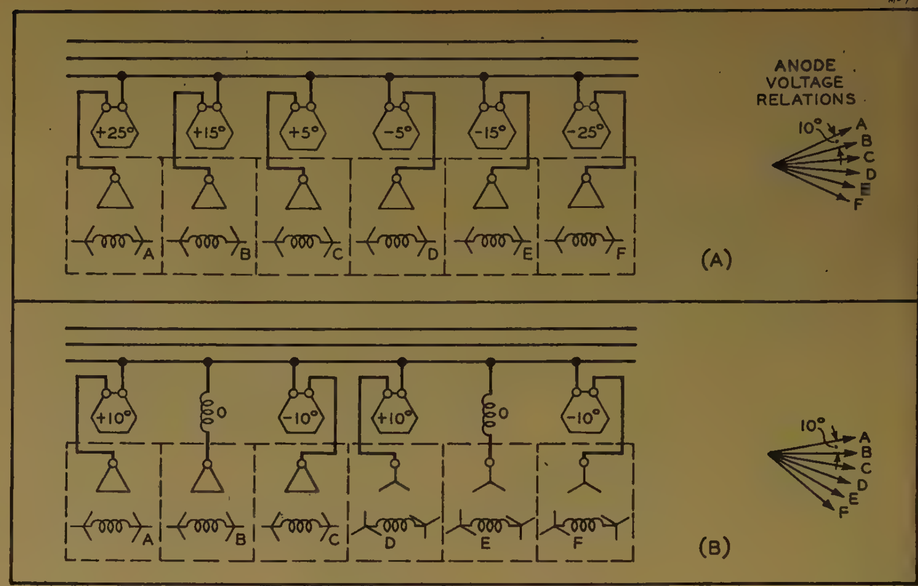


Figure 7. Two methods of providing 36-phase operation with six-phase units and phase-shifting transformers

A. Six like six-phase units
B. Three delta–double-wye units; three wye–double-wye units

To forestall such occurrences it is desirable that all parties concerned in rectifier installations co-operate to investigate at the earliest opportunity the possible effects on co-ordination with communication circuits.

Information on a number of methods of estimating the harmonic voltages and currents produced by rectifiers has been published.[5,6,7] These methods include calculations involving characteristics of the rectifiers and the impedance of the power-supply system at harmonic frequencies. It is necessary to make simplifying assumptions to facilitate calculation, and a very close check between actual and estimated results cannot be expected. Experience does indicate, however, that the methods are useful as a basis of judgment regarding the extent and seriousness of wave-shape distortion.

For many years previous to the war there was extensive growth in power systems, particularly in distribution lines, and communication-circuit exposures were being created on a large scale. During the same period, the wave shape of the power systems was being improved gradually, and this was one factor in making it possible to co-ordinate the two types of circuits without incurring excessive costs specifically for that purpose. The advent of large mercury-arc-rectifier installations has threatened to reverse the trend and is a challenge to the utilities involved.

FUTURE WILL BRING NEW PROBLEMS

About 1938 a large mercury-arc-rectifier installation was put in operation in the United States and excessive noise induction was caused on communication circuits over an extensive area.[8] Development work, in which the manufacturer and the purchaser of the rectifiers and the communication company participated, led to the practical application of multiphase operation as a means of controlling wave-shape distortion. Since that time there has been extremely rapid growth in the installed capacity of mercury-arc rectifiers in electrochemical and electrometallurgical industries. In Eastern Canada alone the installed capacity of mercury-arc rectifiers now totals more than 1,000,000 kw. Multiphase operation has been used widely and has prevented what otherwise would have been widespread co-ordination problems. The types of loads just mentioned are well suited to multiphase operation since it is possible to operate large groups of rectifiers in parallel on both the d-c and a-c sides, and the loads are substantially constant throughout the day. These conditions cannot be expected in all the applications that will be made when rectifiers are available to fill all demands.

As regards the future, new problems can be expected in connection with rectifiers and other types of electronic devices. In addition to use in traction systems and in the electrochemical and electrometallurgical industries, rectifiers have been used widely as a source of direct current for high-power radio stations. It is expected that in the future they will be used wherever conversion from alternating to direct current is required, for example, to supply large d-c motors in steel mills and similar industries. D-c transmission of power has been under development for many years. If it comes into general use, it will involve both rectifiers and inverters, and wave-shape distortion may appear on the a-c systems at each end and on the d-c link. A similar situation will be introduced by electronic frequency changers used either to supply higher-frequency power for industrial purposes or to interconnect power systems of different frequencies.

We do not know the solutions to all these problems or even the precise nature they will take. What can be stated definitely, however, is that the problems can be solved and that the best solutions will be obtained if all parties concerned co-operate wholeheartedly to that end.

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X—Goals in Engineering Education

WILLIAM E. WICKENDEN
FELLOW AIEE

The engineering profession will find it hard to rise above its educational source, and there is no magic through which education can rise above its teachers, declares this educator. More emphasis on the humanistic studies, more time devoted to fundamental science, and a basic analysis of the engineering method furnish the framework of the undergraduate course he proposes.

THIS WAR has made crystal gazers of us all. If each of us were granted a single look into the magic ball, the question most of us would ask would be this: "What does the future hold for the youth of today?" This is a question to keep educators humble—if they need one—but it is the concern of us all. The news columns reflect it. Let any of the oracles of the educational world speak forth—a Butler, a Conant, a Hutchins, or a Compton—and only the President himself commands a wider hearing. The world of education is a world in conflict; it has been so ever since education was invented. Aristotle speaks of the disputes of his day—whether reasoning power, or morals, or useful knowledge, or virtue, or a sense of excellence was the object of education. The moral is that we shall plan our postwar goals provisionally and pragmatically and beware of educational panaceas.

ENGINEERING EDUCATION A SUCCESS

Engineering education stands out in the world of today as a conspicuous success. Let the world judge, if it will, by the lofty mark the poet Milton set, "I call, therefore, a complete and generous education that which fits a man to perform justly, skillfully, and magnanimously, all the offices, both public and private, of peace and war." Milton wrote in the 17th century, in that golden age of generalists. The genius of our age is not Baconian universality; it is rather Einsteinian specialization. We judge education accordingly.

Has the engineer done his job *justly?* Has he stood between capital and labor, between the employer and the employee, between the producer and the consumer, between public welfare and private gain, and served with reasonable impartiality the interest of them all? Not always, not perfectly, to be sure, but soundly and consistently, *yes*. He has done his job just as incorruptibly in the Tennessee Valley Authority or at Grand Coulee or in New Deal bureaus as in the citadels of private enterprise. On the score of *justly*—in Milton's rating scale—we can give him definitely better than an average score.

The second scoring point is *skillfully.* The engineer has always been the chief reliance of American military strategy. A British writer in a recent *Harper's* points out that from the days of George Washington until now our military history has not been written in such heroic episodes as the holding of Thermopylae, or in Napoleonic swiftness of maneuver and suddenness of striking power, or in dramatic charges of a light brigade at Balaclava, but in standing the enemy off while we build up such overwhelming material striking power and such command of the lines of supply that we are at last able to strike the blow which cannot be parried. American engineering has answered that question of *skillfully* in a way that can never be forgotten. The god of war is on the side of the heaviest industrial potential and the best organized lines of supply.

Finally, what about *magnanimously?* Here is a word which means "high-souled, above petty feelings." For a specialist like the engineer magnanimity really means being a good teammate. Does he insist on being captain or will he play just as well in a secondary capacity? Will he let the team have the credit, or insist on the spotlight for himself? Can he applaud what men of other training and gifts contribute—the lawyers, the accountants, the economists, the specialists in public relations, and the politicians—or does he think the whole team should be engineers like himself? Will he put his work above his pay, his standards of excellence above a cheap expediency, his pride of achievement above applause, his integrity above a a dubious fee or a shady profit? The world knows the answer—rate the engineer high under the item *magnanimously.*

CONTRIBUTION TO ARMED FORCES

Engineering education has given to industry and the Armed Forces not a slender caste, but strength of numbers; to numbers it has added an elite of advanced scientific skill; to skill in research it has added resourcefulness in invention; to inventive power it has added the priceless ability to get things done. To technical skill it has added a growing capacity for administration. Its graduates have been soundly oriented. They have been able to keep their poise amid the turmoil of economic conflict and social controversy.

To all their normal and special war training functions engineering colleges have added an invaluable contribution to the mobilization of war effort on the laboratory front. This is a public function of the engineering colleges which deserves to be far more widely recognized and supported—that of maintaining at all times a great liquid pool of scientific equipment and research skill which can be mobilized in any emergency, be it local or global, for the service of industry, or civil government or the Armed Forces. The colleges are thus the indispensable mobile arm of our entire scientific and technical establishment.

Beyond all doubts engineering education has been a success. With all the models to choose from, the Army and the Navy unhesitatingly have chosen the technological model, to the dismay of the liberal faculties who had assumed that theirs was the only "complete and generous" education, for

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undergraduates at least, that met Milton's standards. Every present indication of the day when millions of war veterans will return to the unfinished business of their education points to a crowding of the technological schools beyond all previous records.

TOMORROW'S ENGINEERING EDUCATION

Tomorrow's engineering education is going to be good general education; it is going to be good humanistic education, as well as good scientific education, and good technical education. In the colleges more time and relatively much more emphasis will be given to humanistic studies—English, history, social institutions, economics, and psychology—and to the sources of enjoyment and of spiritual enlightenment in literature, the drama, the fine arts, religion, and philosophy. Less than a year of the undergraduate period devoted to this realm—distributed, of course, through the whole curriculum—will be scored as under par. By the same token, more time and relatively more emphasis will be devoted to fundamental sciences. More men will study beyond calculus; two years will be devoted to general physics instead of one and possibly to chemistry as well. Combining the sciences and the humanities, the average engineering student will receive fully $2^1/_2$ years of work that will be accredited in any liberal-arts college in the land.

There are solid, even compelling, reasons for this effort to give the young engineer the soundest possible general education, and yet to do it within the framework of the engineering curriculum. For one thing, he is to be not only an engineer but a citizen, sharing equally with all other educated men the responsibility for national security, civic welfare, cultural advancement, and organized community life. The sooner we in the United States rid ourselves of the idea that these are the special responsibilities of an elite group, to be trained in colleges set apart from the working concerns of life, the better. Then too, the engineering graduate is not only a scientific technician but a prospective executive. Fifteen years after graduation three out of four will be engaged principally in directing the work of other men. Whether as expert technicians or as executives, engineering graduates will be working under a professional code which demands not only an ethical standard of personal integrity, but also certain social obligations beyond the range of immediate outcomes of their work. To an increasing degree engineers must hold their own in teamwork with men trained in the social sciences, that is, with economists, sociologists, psychologists, and political administrators. This can come only through the command of a common language and a common standard of values.

On the scientific side, the permanent values in an education are not in details of technique which are growing obsolete before they are incorporated into textbooks, but in principles and relations which are of enduring validity. Slide-valve engines may yield to steam turbines and gasoline engines to jet propulsion, but Newton's laws of motion and the first and second laws of thermodynamics will stand, and engineers are still far from exhausting their potentialities. The chief weaknesses in engineering disclosed by the war are said to be due to inadequate grasp of fundamental physics, and it is a somewhat startling commentary on the scientific foundations laid only a decade ago that so few men who were graduated in that period have been able to master the most recent applications of electronics and of ultrahigh-frequency radiation.

If engineers are to receive as good a humanistic and scientific education as they should, it is inevitable that there will not be enough time left in the undergraduate period to afford both a rounded view of engineering fundamentals—structural, electrical, mechanical, and the like—and a substantial technical grounding in some major branch of engineering application. Pruning becomes inevitable, and judicious pruning calls for a critical evaluation of what is to be kept and what is to be cut away.

MASTERY OF ENGINEERING EDUCATION

The best thinking of engineering educators on this point is that the permanent values of the senior stage of the curriculum do not lie in any detailed knowledge of subject matter or technique, but rather in an introductory mastery of the engineering method. This is a way of using knowledge, rather than knowledge itself. It is a method of analysis, of procedure, and of evaluation, to be applied to new situations, rather than a familiarity with standard solutions already arrived at. It is not a course in any particular subject, but a process that cuts across the various areas of subject matter. It is an active process, applied by the student to problems and projects of the right degree of difficulty, and not a passive process of hearing lectures and witnessing demonstrations. It draws on generic principles and the corollaries derived from them, on the basic assumptions used to make complex situations manageable, on the data of empirical observation, on the codified experience embodied in standards and recorded in handbooks and manuals. It makes use of judgment factors beyond the limits of rational analysis. Finally, it employs the criteria of cost and return which is known by the name of engineering economy. It is this method which distinguishes engineering from science, and it is one way of distinguishing an engineer from a chemist or a physicist.

The detailed technique of engineering practice is a goal that must wait for the postgraduate or the postcollege period. A good many people have argued that the way to meet that problem was to make the engineering curriculum a five- or six-year course. Most educators have come to think that a better job could be done by adding to a four-year course an extension that is tailor-made for the individual after he has discovered his particular needs, rather than something ready-made for all in advance. Until the war broke out, engineering college in the urban industrial centers were growing especially active in part-time and evening graduate work to meet this need. Some industrial concerns have done splendid work in providing means by which young graduates go on in the study of advanced fields of engineering, as well as the usual training courses intended to familiarize college recruits with the organization, personnel, geography, routines, and products of their business.

Now that we have projected a route map for postwar engineering education, let us go back and quickly sketch in some of the details. From all present indications the engineering schools are going to have the call on a high proportion of our ablest young men. This is the time to put admissions on a selective basis. A second reason for doing so is the promise of a large-scale development of a semiprofessional type of technical education in technical institutes, as in New York State, and in junior colleges, as in California. A lot of practical-minded boys who in the past have turned toward the engineering colleges are going to have somewhere else to go, with a better chance of success in a more intensive and more directly practical type of training.

The methods by which the Army and the Navy have selected young men for their college programs have furnished confirming proof of what engineers have long believed, that high-school graduation supplemented by a test of scholastic aptitude is not sufficiently discriminating for the selection of qualified students of engineering. These tests, incidentally, have revealed rather shocking variations in secondary-school preparation in various parts of the country. Measures of scholastic attainment and aptitude which will be more valid for engineering are now being developed in a co-operative project aided by the Carnegie Foundation. These measures, taken in conjunction with greatly improved personnel techniques which can be adapted from the experience of the Armed Forces, give promise of marked gains in the effectiveness of engineering education. These selective-admission practices have an important economic aspect. In the past the average engineering college has graduated less than half the students admitted. The quickest and by far the cheapest way to increase the capacity of engineering colleges to meet rising postwar demands is simply to select better educational risks.

A more discriminating selection of students may give more homogeneous human material, but there still will be wide differences in endowment, preparation, pace

and intellectual interest. Engineering education will never be really efficient so long as these boys are al. run through the same mill. A higher degree of success in reaching a more modest goal would be a wholesome experience for some, while others should be set to far more challenging tasks if their real abilities are to be engaged. The humanistic section is one of the most promising in which to begin. No matter how carefully students are selected for general aptitude and ability, some will enter college with highly developed language skills and with the benefits of travel, observation, and wide reading; others, equally worthy, will be but little removed from alien backgrounds or extremes of native provincialism. Enrichment for the former, through wider excursions into the areas of literature, art, history, and other social studies, and more effective grounding in fundamentals for the latter would seem to be worth-while goals.

Early in the postwar era engineering colleges may find themselves forced to choose between technical specialization and functionally differentiated programs for their upperclassmen. The best thought among engineering educators is that undergraduate curricula should be narrowed down to a few major classifications, corresponding to the dominant arms of the profession. No psychologist can tell whether a boy is better qualified to be a civil or a mechanical or a chemical engineer; what he does think is that one might be able to recognize in a student by the senior year budding promise in such areas as research and development, analysis and design, production and operation, and administration and commercial relations. Let higher orders of technical specialization wait until after graduation and some early experience, would be the psychologist's advice, and give the senior a chance to develop a bit along one of these functional lines.

PROJECT METHODS OF INSTRUCTION

In recent years educators have been growing rather shamefaced about their adding-machine methods of counting up educational credits. In far too many cases the formula has been that 120 or perhaps 140 credits in the registrar's books equals one bachelor of science degree. This gives too much encouragement to the temporary bolting and prompt regurgitation of scholastic fare, soon happily forgotten. The teacher who won out in the competition for the student's time and effort was the one who sent him home with overnight chores to do. We are moving toward project methods of instruction, and overall methods of testing which are concerned with the student's power to do, as distinct from piecemeal measurement of achievement. Engineers may be thankful that they were graduated before the comprehensive examination was invented, but they will like the youngster who can handle one with distinction better when they come to hire him.

In the colleges with real scientific talent on their staffs, organized research has experienced a great boom from the war. Some of this growth will be transient, but the permanent gains still will be notable. Time, indeed, may show it to be the greatest thing that has happened to engineering education in 50 years. For one thing, it transforms the atmosphere of a college from that of a glorified sort of schoolhouse to a place where real things are happening. At its worst, it drains superior talent away from the classroom and leaves the student to the uncertain ministries of the routine teacher. At its best it does something for an engineering school that is closely equivalent to what association with a great hospital does for a medical school. An engineer is a man who spends his life in solving problems. He can best learn this art as a disciple, under men actively engaged in solving problems—real ones, not exercises in the back of a book. Research gives the teacher a ready-to-hand means of balancing scholarship with practice. It offers him exceptional opportunities for professional recognition and prestige. Within reason, it offers opportunities for an earning power which will make the academic world more attractive to men of ability. To the college, it offers means of augmenting equipment and spreading overhead expense. To the nation, it offers the possibility of maintaining a liquid pool of scientific manpower and equipment which may be mobilized quickly in a period of crisis. The task which confronts educators is not merely to assure the continuance of research activity, but to gear it most effectively into teaching activities.

STRENGTHEN COLLEGE FACULTIES

Chief among postwar goals must be the immediate rehabilitation and the progressive strengthening of college faculties. War service is taking a heavy toll of depletion and of exhaustion. Abrupt curtailments of military-training programs and the vacillating policy on student deferments, now turned wholly negative, are tending to a dispersion of forces little less than tragic. Meanwhile virtual cessation of graduate instruction has dried up the normal source of teachers. If thousands of returning veterans crowd into the colleges before these losses can be repaired heaven help the colleges and them. The entire profession will be hit hard by the accumulating deficits in the higher levels of training, and colleges will be ill-financed to compete with industry for such talent as exists.

The plain truth is that these seedbeds of the engineering profession are going to need its protecting hand and that of industry. If you raid them for manpower, you may live to regret it. Colleges must find money somewhere to pay for high-grade leadership. Probably the best way for industry to help is to finance research projects that will keep men of superior talents on college campuses and to encourage colleges to engage engineers and research scientists of distinction as clinical professors for part-time teaching. The profession will find it hard to rise above its educational source, and there is no magic through which education can rise above its teachers. New curricula, expanded laboratories, co-operative plans, new techniques of personnel selection and work evaluation—these things are tools, and they can never be stronger than the hand that wields them.

Out of sheer necessity, engineering colleges will have to put more effective efforts into the development of young teachers. Competition will compel us to catch them young, to give them a vigorous tryout, to work out with them tailor-made plans for their individual development, to stake them through advanced stages of training and experience, and to push them into stimulating relations with the active world beyond our campuses. I cannot imagine a more fascinating and rewarding task for an educational executive, for it is one in which I am sure industry can be induced to give enlightened co-operation, and to which alumni and friends of education can be induced to contribute funds.

Finally, let us take as our goal a profession truly conscious of its destinies. Engineers today are a divided body, vaguely groping for their place in the sun and only half aware of their common responsibilities; yet it is probably no exaggeration to say that no other profession and no other branch of education have had such an opportunity to enlarge their sphere of influence as awaits engineers in the postwar world. The essence of a profession is social trusteeship. A physician is expected not only to be skilled in the arts of diagnosis and of therapy, but also to guarantee in company with his fellow physicians the standards and facilities of the health service offered to his community. A lawyer is expected not only to be skillful in drawing legal instruments, in pleading cases, and in composing disputes, but also to join with his colleagues in guaranteeing the standards of justice in the courts and legislative bodies. One requires of a clergyman not only the services of a spiritual adviser and minister, but also that men of the cloth unite in giving voice to the public conscience and force to public morals. Likewise, an engineer is asked not only to be expert in the technique and economy of materials and energy, of structures and products and utility services, but also to guarantee that society will reap the fruits of scientific advance and technical progress in general wellbeing.

Such a guarantee cannot issue solely from engineering efforts in the laboratory and the plant; it is inseparable from matters of public policy and administration. Shall research be free or regimented? Shall the protection of the patent system

be denied to the fruits of corporate research? Shall the national fiscal policy favor or inhibit capital risks? Shall we be more intent on policing the capital and price structure than on encouraging technological improvement? Shall free enterprise be fostered in areas where great possibilities of technical advance exist? Shall management be always suspect, and labor deemed incapable of doing wrong? Shall natural resources be nationalized? Our professional future and its potential fruitfulness to society are inseparable from these and kindred social issues.

There can be no powerful and unified engineering profession tomorrow unless it is created today in the consciousness of engineering students. We educators must do that job, and you must lend your interest and encouragement. In this hour when the prestige of engineering stands high and when engineering education stands forth, as never before crowned with success, let there be no hypnotic self-satisfaction, no seductive complacency among us. This, gentlemen, is the time to mark up our goals!

Grounding Principles and Practice

II—Establishing Grounds

CLAUDE JENSEN
ASSOCIATE AIEE

GROUNDING has become an everyday electrical term and a very common practice in electrical construction and operation. The primary function of most grounding is to increase safety for life and property. Its secondary function is to improve the operation and continuity of service of electric systems. These two functions are often complementary and compatible.

There are a number of methods for making ground connections. The essential requirements are that they shall be durable, have low resistance, have adequate current-carrying capacity, and be economical to install.

This article is a general treatment of the various types of ground connections, their characteristics, methods for improving ground connections, and methods for measuring ground resistances. It is based on the experiences and developments of the industry.

TYPES OF GROUNDS

In general, ground connections may be divided into two groups or classes. The first comprises water pipes, metal frameworks of buildings, well casings, and other metal structures or materials installed for purposes other than grounding. If located near the equipment or circuit being grounded, they can provide convenient and economical types of grounds.

The other group comprises driven electrodes, buried plates, strips, and conductors, and other kinds of specially designed electrodes. These are intended solely for the purpose of making a ground connection and are installed at, or as near as practicable to, the location where the ground connection is desired.

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WATER PIPES

As a means of grounding electric systems, such as secondary lighting services and telephone services, water pipes probably come first from the standpoint of economy. In urban areas, they usually extend over the same area or territory as that covered by the electric-lighting and telephone systems, and are therefore readily accessible at service pipes and at other places. Consequently, ground connections to them are economical in first cost.

Because of the great extent of water-piping systems, they offer good conductance to the flow of current into the earth. In many instances, the resistance of a water-pipe ground connection is of the order of a fraction of an ohm and a value of two to three ohms or more would be considered as excessive. This comparatively low resistance may be attributed mainly to the wide extent of such systems and the tremendous volume of earth affected. In many instances, pipes are many miles in length, and sizes range from the ordinary service pipe to mains a foot or two in diameter or even larger depending upon the water system of the particular city.

This article is the second of five based on a series of lectures on the subject which was sponsored by the power and industrial group of the AIEE New York Section during the 1943–44 season. Various types of ground connections, together with methods for measuring ground resistance, are discussed.

The types of soil in which water pipes are embedded may have a wide range of resistivity values. However, this has relatively little effect on the resistance of the ground connection because of the wide extent of the system. Also, the pipes are usually installed at depths below the frost line where the moisture is relatively permanent and where the resistance is little affected by seasonal variations.

On the other hand, the type of joints used in water-piping systems will affect the resistance. Where lead or screw joints are used for joining together lengths of pipe, these usually provide good metallic connections and the resistance is so low as to be almost negligible. In comparison to this, where joints are made with cement or "leadite," resistances may range from several ohms to several hundred ohms and such systems are consequently not good for electrical grounds. However, water-piping systems are widely used and, in general, are satisfactory for many purposes.

METAL FRAMEWORKS

Structural metal frameworks of buildings which make direct contact with the soil and are dispersed over an extensive area of ground may also be used for ground connections. This type of ground is permitted by various codes as an alternate method of grounding when a water-piping system is not available.

The National Electrical Code states that metal frames of buildings have, in general, a resistance substantially below 25 ohms. This depends on the size of the building, the type of footings, and the soil at the particular location. Tests reported by one investigator gave values of 2.4 and 2.2 ohms for steel frameworks of two relatively large buildings.[1] Resistances of this order

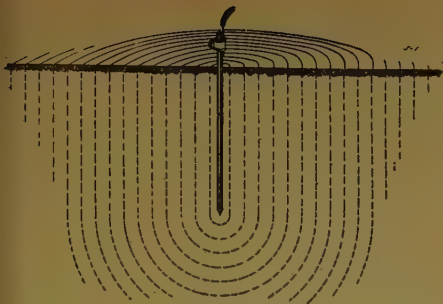


Figure 1. Resistance of earth surrounding an electrode

This may be pictured as successive shells of earth of equal thickness. With increased distance from the electrode, the earth shells have greater area and therefore lower resistance

compare favorably with those of water-pipe grounds and connections to them should provide satisfactory ground connections. However, measurement of resistance is the criterion in determining the suitability of grounds of this type.

WELL CASINGS

Steel pipe used as casings in wells is sometimes used for making ground connections at substations and also in rural areas where a well is located near to the system or equipment being grounded. Usually such pipes extend a considerable distance into the earth and can affect a tremendous volume of earth so that grounds of this type should be comparatively low in resistance. One reference mentions a substation-ground connection to a 14-inch-diameter steel casing 100 feet in length which had a resistance of approximately 1.3 ohms.[2]

In using any of the foregoing methods for making ground connections, it should be remembered that they serve a twofold purpose. One is the original purpose for which the equipment was installed, and the other is its use as a ground connection.

Any changes or alterations in the equipment or facilities as related to the original purpose may affect its use or functioning as an electrical ground. For example, the removal of a water meter would disconnect the water pipes in a building from the service pipe and street mains.

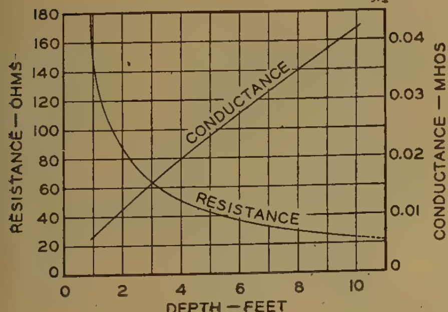


Figure 2. Effect of depth on resistance and conductance of a driven ground for uniform soil resistivity

Table I. Resistances of Different Types of Soil

From Bureau of Standards Technologic Paper 108

Grounds Tested	Soil	Resistance in Ohms: Average	Minimum	Maximum
24	Fills and ground containing more or less refuse such as ashes, cinders, and brine waste	14	3.5	41
205	Clay, shale, adobe, gumbo, loam, and slightly sandy loam with no stones or gravel	24	2.0	98
237	Clay, adobe, gumbo and loam mixed with varying proportions of sand, gravel, and stones	93	6.0	800
72	Gravel, sand, or stones with little or no clay or loam	554	35	2,700

Certain precautions are therefore necessary to prevent any break in the path to earth. In the case just mentioned, the National Electrical Code requires that if the ground connection cannot be made on the street side of the meter, the water-piping system shall be made electrically continuous by bonding together all parts which are liable to become disconnected.

DRIVEN ELECTRODES

Considering the group or class of grounding electrodes which are installed solely for the purpose of making a ground connection, the driven electrode is used far more than the other types. This results from its numerous mechanical and electrical advantages as compared to other types of installed grounds such as buried plates, buried strips or cables, grids, and so forth. The outstanding advantage is the low cost of driven grounds compared to the other forms of grounds, also the simplicity of driving a rod compared to the task of excavating for and installing buried electrodes. In addition to this, the ground area required for a driven electrode is small, which is a decided advantage in locations where excavation is difficult or where space is limited.[3]

Another important advantage is that the connection between the ground wire and the driven electrode can be made above the surface of the ground, which makes it convenient and easy to inspect the connection or to disconnect the ground lead if it is desired to test the resistance of the ground.

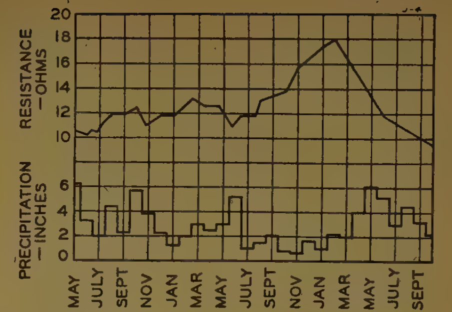


Figure 4. Seasonal variation in resistance with rainfall

The conductance of a driven electrode compares very favorably with that of other types of installed grounds. It has the advantage that two or more electrodes may be driven and connected in parallel and, for a given cost, it is possible to obtain a much lower resistance with driven electrodes than with other types of installed grounds.

Where the permanent moisture level or a layer of better conducting soil is at a considerable depth below the surface, rods can be driven to a depth far beyond that which would be practical or economical for buried grounds. Furthermore, the use of artificial treatment as a means of reducing the resistance of a ground lends itself more readily to driven electrodes than to the other types.

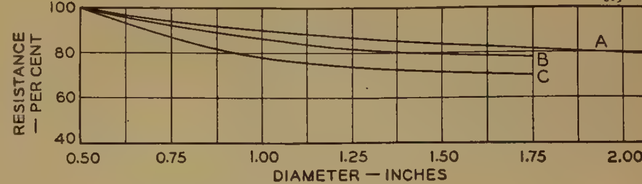
These advantages of the driven electrode account for its widespread use. However, to secure the best results in practice, an understanding of the general principles and characteristics of driven grounds is necessary.

CHARACTERISTICS OF DRIVEN GROUNDS

Although the earth may be considered as a conductor which has practically unlimited conductance capacity and, on account of its size, negligible resistance, it cannot be assumed that all connections to the earth will have the same characteristics. The electrical conductance of soil is determined largely by its chemical ingredients and the amount of moisture in the soil.

That the resistance of a ground connection is dependent mainly upon the type of soil surrounding the electrode is shown in Figure 1. This is pictured as cylindrical

Figure 3. Effect of electrode diameter on resistance of a driven ground



A—From Bureau of Standards technologic paper 108
B—Average of Underwriters Laboratories tests at Chicago
C—Average of Underwriters Laboratories tests at Pittsburgh

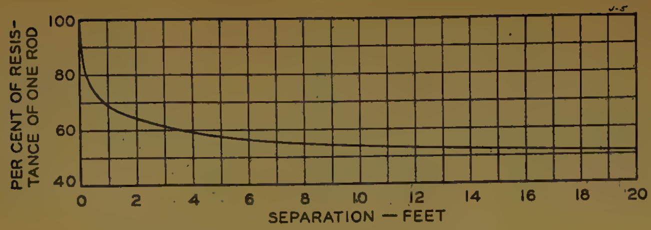


Figure 5. Variation in resistance with distance apart of two electrodes connected in multiple

shells of earth of equal thickness. The greatest resistance is in the shell immediately surrounding the electrode which is the region of smallest cross section at right angles to the flow of current through the soil. Each succeeding shell has an increased cross section. At a distance of eight to ten feet from the rod, the area of the path is so large that the resistance is almost negligible. The resistance varies inversely as the cross section, and therefore, in the area within a few feet from the electrode, where the conducting path is small, the resistivity of the soil is an important factor. Measurements show that 90 per cent of the total electrical resistance surrounding an electrode is generally within a radius of six to ten feet from the electrode.

The wide variation in soil resistance is illustrated in Table I which is based on measurements made by the Bureau of Standards on different types of soil.[4] As will be seen, values as low as 2.0 ohms were obtained in some soils, whereas for others, the resistance was as high as 2,700 ohms. Even wider variations than these are possible.

CONTACT RESISTANCE BETWEEN METAL AND EARTH

The contact resistance between a ground electrode and the soil can be considered as negligible compared to the resistance of the soil itself, for the metals commonly used for driven electrodes. This assumes that the metal is clean and free from paint or grease and that the soil is firmly packed around the electrode.

The contact resistance between metal and soil has been determined from tests by the Bureau of Standards.[4] In these tests, several samples of earth were used, each of which was thoroughly mixed before testing, to insure as uniform resistivity as possible. Tests were made by placing different quantities of soil in a cylindrical glass vessel having an iron bottom, compressing it by forcing an iron piston down upon it and measuring the electrical resistance between the piston and the metallic bottom. These measurements indicated that the effect of contact resistance between clean electrodes and earth, when firmly pressed together, is negligible, since the readings showed the same specific resistance for different depths of soil in the cylinder.

EFFECT OF DEPTH

The depth to which an electrode is driven is probably the most important factor affecting its resistance. There are several reasons for this. First, the volume of soil affected increases directly with the length of electrode below the surface, and second, the soil resistivity usually decreases with depth by virtue of the increased moisture content.

Figure 2 shows the variation of resistance with depth of a driven electrode. This curve was plotted from calculated data assuming soil with uniform resistivity.[4] Although this is a theoretical curve, it has been checked and verified experimentally by various investigators, with only slight inconsistencies due to nonuniformity of the soil.

In actual practice, soil is seldom of uniform resistivity and so, practically, the curve shows only what minimum depth in conducting soil it is desirable to reach. For example, it will be seen that the decrease in resistance is small for each additional foot greater than about eight feet. Assuming that relatively permanent moisture is reached at this depth, it would appear that eight feet would be an economical depth. However, where the resistivity decreases with depth, as well as where permanent moisture exists at some distance below the surface, the use of longer electrodes is advantageous.

A useful curve in analyzing the effect of length is the conductance–length curve as shown on Figure 2. In comparison with the resistance curve, which levels off, the conductance curve is practically a continuous upward sloping line indicating that electrodes longer than eight feet are beneficial.

The length of a ground rod is also of importance in localities where winter seasons are very severe and where grounds must function in winter as well as summer. The resistivity of frozen soil is very high compared to that of soil at normal temperatures.[5] Hence, grounds should extend well below the frost line, otherwise the resistance is apt to vary considerably throughout the year. Even when driven below the frost line, there may be some variation as the upper layers of soil, when frozen, have the effect of shortening the active length of the electrode in contact with soil of normal resistivity.

DIAMETER OF ELECTRODES

The minimum diameter of a driven electrode is determined by mechanical rather than electrical considerations. The usual practice is to select a diameter only large and strong enough to drive it into the soil at a particular location without bending or splitting.

The effect of electrode diameter on the resistance of grounds is shown in Figure 3. Curve *A* is a calculated curve assuming uniform soil resistivity.[4] Curves *B* and *C* represent the average of hundreds of actual measurements on grounds in two different cities.[6] Considering the diameters used commercially today, from curve *A* it will be seen that doubling the diameter from one-half inch to one inch decreases the resistance of a single driven ground by only $9^1/_2$ per cent.

SOIL RESISTANCE AFFECTED BY SEASONAL VARIATIONS IN MOISTURE

Seasonal changes in ground resistance vary more or less with the amount of rain throughout the year. Ground resistances are likely to be high following a long dry spell and likewise, lower after heavy rains. Figure 4 shows the variation in ground

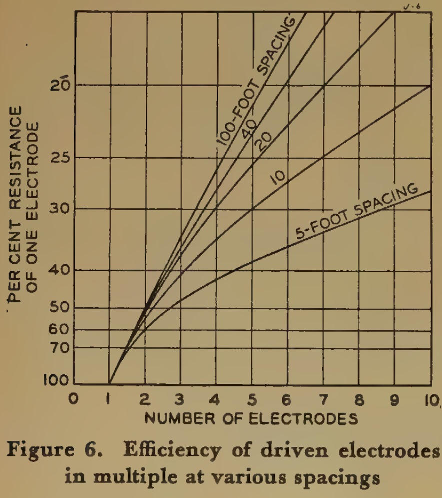


Figure 6. Efficiency of driven electrodes in multiple at various spacings

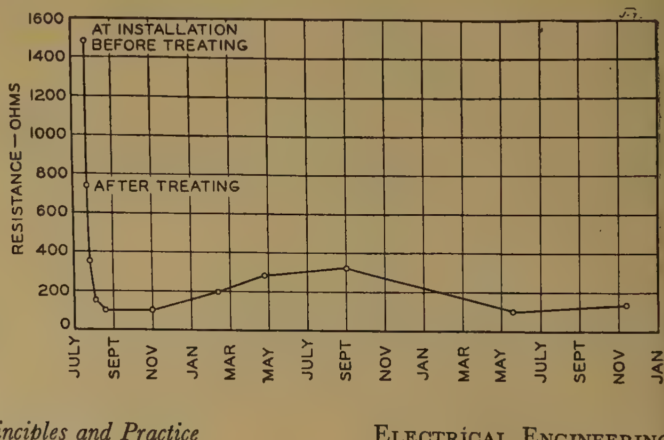


Figure 7. Ground resistance reduced by soil treatment

resistance with precipitation which occurred at one installation.

The normal moisture content of soils ranges from about 10 per cent in dry seasons to around 35 per cent in wet seasons with an approximate average value of about 16 per cent to 18 per cent.[3] Tests by the Bureau of Standards showed that when the moisture content is below 22 per cent, the resistivity increases very rapidly.[5] It may be seen from this that seasonal variation in rainfall can affect the resistance of a ground connection to a considerable extent.

METHODS FOR IMPROVING GROUNDS

Where the resistance of a driven ground connection is very high or in excess of a value considered satisfactory for a particular installation, there are various methods which can be used for improving the resistance of the ground. These are the use of multiple electrodes, soil treatment, a combination of multiple rods and soil treatment, or deep-driven electrodes.

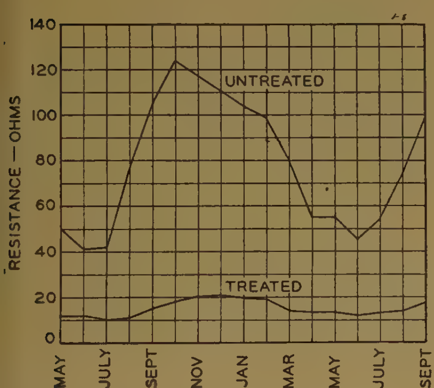


Figure 8. Ground treatment lessens seasonal variation in resistance

MULTIPLE ELECTRODES

One of the most convenient and economical methods is by means of multiple electrodes. When two driven electrodes, well spaced from each other, are connected in multiple, they provide two parallel paths to earth. Since 90 per cent of the total resistance is located within six to ten feet of an electrode, these rods should be spaced far enough away from each other to minimize the tendency for overlapping of the current paths away from the electrodes. The effect of spacing on the resistance of two electrodes connected in multiple is shown in Figure 5.[4]

With wide spacings, each additional driven electrode introduces a new cylinder of unused soil and the combined multiple resistance is decreased by an amount approximately inversely proportional to the number of electrodes; that is, two rods in multiple tend to have one-half the resistance of one rod, three rods, one-third the resistance, and so on.

This direct reciprocal relation is not quite reached in practice, however, as the spacing is necessarily limited and the conducting paths or cylinders surrounding the rods tend to overlap. This point is illustrated in Figure 6. Two rods at 100-foot spacing would have approximately 50 per cent of the resistance of one electrode, but spacings of this order are often impractical. Also, the resistance and reactance of long leads necessary for connecting electrodes at wide spacings would tend to decrease the effectiveness of rods in multiple. However, with spacings of 10 to 20 feet which are generally feasible, the reciprocal relation can be closely approached.

The characteristics of multiple-ground-electrode systems have been discussed in numerous technical articles and papers. In an article by H. B. Dwight,[7] curves are presented showing the relationship between the number of electrodes, the spacing, ground area, conductance and effectiveness. Similar data are also given in an article by J. R. Eaton.[8] This information may be useful in designing station grounds where large numbers of electrodes in multiple are used.

SOIL TREATMENT

Artificial treatment of the soil surrounding a driven electrode is often resorted to as a means of lowering the resistance of a ground. Substantial reductions in the resistances of electrodes already installed may be accomplished by dissolving in the moisture normally contained in the soil some substance which is highly conducting in its water solution.

There are a number of chemicals suitable for this purpose, such as sodium chloride, magnesium sulphate, copper sulphate, and calcium chloride. Other chemicals which have been investigated are iron sulphate, sodium nitrate, potassium nitrate, and ammonium sulphate. The selection is largely dependent upon cost, availability, and the corrosive properties of the chemical. Common salt and magnesium sulphate are most generally used.

Chemical treatment can affect reductions in soil resistance anywhere from 15 per cent to 90 per cent. The benefit which can be gained is dependent mainly upon the kind and texture of the soil. Figure 7 illustrates the results obtained for one installation. The percentage reduction in this case is rather high and typical for grounds having high resistances. Grounds of lower resistance may be improved by treating but not in the same proportion.

In addition to lowering the resistance of a ground, soil treatment also smooths out seasonal fluctuations, as shown in Figure 8. The curve for the treated ground shows some variation, but it is not nearly so great as for the adjacent untreated ground.

Chemical treatment has one disadvantage in that its effect is not permanent, the solutions being gradually carried away and dissipated by the natural drainage in the soil. The rate of dissipation is dependent upon the porosity and type of soil and the amount of rainfall. Renewal of the treatment may be necessary after a few years or when periodic tests indicate a constant increase in the resistance. This is illustrated in Figure 9 which shows that the effect of soil treatment was completely dissipated after a period of five years and the resistance was then the same as that of an adjacent untreated rod.[9]

METHODS OF APPLYING SOIL TREATMENT

A typical method for installing soil-treating material is to place the chemical in a circular trench around the electrode as shown in Figure 10. This is effective in that it not only prevents direct contact of the chemical with the electrode, but also the materials are advantageously placed so that the solution spreads through and affects a greater volume of soil than when placed directly around the electrode.

Certain chemicals, such as common salt, calcium chloride, copper sulphate, and iron sulphate when placed in direct contact with electrodes and in the presence of moisture, tend to cause corrosion of the electrode. However, by placing them in a trench as shown, they do not come into direct contact with the electrode. As the crystals are gradually dissolved by rainfall, the solution permeates through the soil to the electrode and since the solution is relatively weak compared to the concentrated chemical, the corrosive action is minimized.

Another method of treating which has been used is to place the chemical in a tile pipe 16 to 18 inches long alongside the electrode as shown in Figure 11A. This method is convenient where space is restricted. It is also effective in preventing direct contact of the treating material with the electrode. However, with this method,

Table II. Low Resistances Obtained With Deep-Driven Grounds

Description of Soil	Length of Sectional Rod, Ft	Ground Resistance Measured at Various Depths When Installing Rod: 8 Ft	16 Ft	24 Ft	32 Ft	40 Ft	48 Ft	56 Ft	64 Ft	Remarks
Clay	64	29	14	8	4.5	3	3	3	3	
Clay	48	270	230	48	13	10	6			
Clay	32	140	45	15	5.5					
Clay	40	75	45	21	8	4				
Clay	48	50	23	18	8.5	5.5	2.5			
Sand and clay	32	200	22	11	9					Struck hard layer, 28 feet
Clay	32	45	30	9	2					Struck stone at 24 feet
Sand	40	200	55	40	33	16				Salted ground

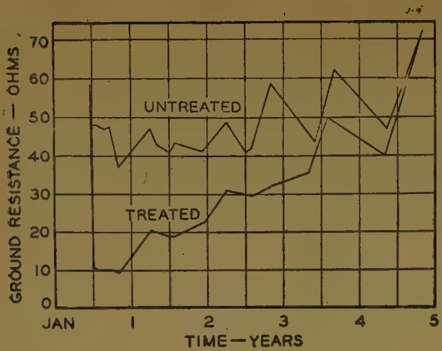
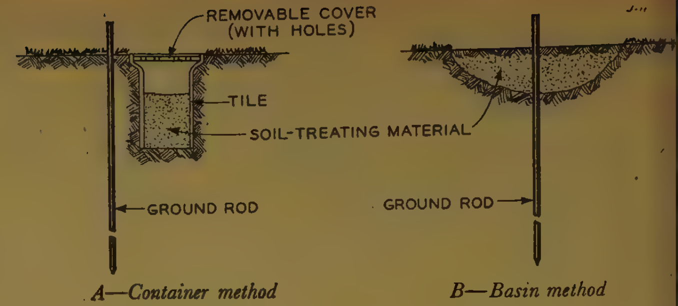


Figure 9. Variation of resistance to ground with time for adjacent electrodes

Figure 11. Container and basin methods of soil treatment



the chemical is more concentrated and at least, initially, is not so effective as the trench method.

A third method which has been used is to place the chemical in a basin directly around the electrode as shown in Figure 11B. The objection to this method insofar as corrosive chemicals are concerned has been mentioned previously. Where chemicals have relatively little or no corrosive effect on the electrode, such as when magnesium sulphate is used, the basin method is applicable.

In using any of these methods, it is advisable, particularly during dry periods, to flood the ground thoroughly with water after installing the chemical, so that the solution immediately will start penetrating into the soil. Otherwise, some time may elapse before sufficient solution resulting from normal precipitation permeates through the soil to lower the resistance of the ground.

MULTIPLE RODS AND SOIL-TREATMENT

In cases where it is necessary to overcome exceedingly high ground resistances, a combination of multiple electrodes and chemical treatment of the soil is often very effective.

DEEP-DRIVEN GROUNDS

Where a single electrode of ordinary length has an extremely high resistance, the use of deep-driven grounds is often helpful in obtaining lower ground resistances. For example, Figure 12 illustrates graphically the relation between the character of the soil and the resistance at one ground installation. In this case, a ten-foot rod driven in sandy soil had a resistance of 250 ohms. It would have taken something over five ten-foot rods in multiple to approach a 50-ohm ground. However, by extending the ground rod through the sand, it was found that the resistance decreased substantially at about 15 feet depth, and a value of 50 ohms was obtained with a single 20-foot rod. This is a typical example of where deep-driven grounds can be helpful and economical.

For grounds requiring electrodes from 15 to 20 feet in length, it is possible to use rods of a single continuous length. However, the handling and driving of long rods is somewhat of a problem and sectional rods provide a convenient and practical method for installing deep grounds.

One type of sectional rod is made in sections eight or ten feet long of various diameters and with threads at both ends. In practice, the first section is driven using a coupling and a driving bolt at the top end. When this is driven to the ground line, a second section is coupled to the first and the driving continued. In this way, long rods are handled nearly as easily as ordinary-length rods.

Table II shows some typical resistance readings obtained with sectional rods and illustrates good applications for deep-driven grounds. In the second example, for instance, a 16-foot rod had a resistance of 230 ohms. By extending the depth to 24 feet, the resistance dropped to 48 ohms, indicating that the rod had penetrated into the lower resistivity soil. With a 48 foot-rod the resistance of the ground was reduced to six ohms.

A typical example of the use of deep grounds is cited by one power company which uses sectional rods in lengths up to 100 feet for improving the resistances of transmission-tower grounds. These have been effective in reducing the resistance to the order of five to seven ohms per structure.[10]

BURIED PLATES

The use of buried metal plates as a means of grounding electric systems has been confined largely to station grounds. However, the use of this type of ground connection appears to be decreasing which is probably due to the fact that the desired results can be obtained with other methods and with much less expense. As there are cases where plates are used, a brief discussion of their electrical characteristics may be of interest.

The same general principles as already discussed for driven grounds apply to plate grounds. Apparently the preferred practice is to bury plates on edge, since less excavation is required than when buried horizontally. Also when backfilling, it is possible to obtain more satisfactory contact with the soil as the earth can be packed firmly on both sides of the plate. Insofar as electrical performance is concerned there apears to be little difference between the resistance of a plate when buried on edge or when laid horizontally.

VARIATION OF RESISTANCE WITH DEPTH

The curve showing variation of resistance with depth of a plate electrode is similar to the curve for the resistance of two driven electrodes in multiple. (See Figure 5.) Assuming uniform soil resistivity, the resistance decreases rapidly with the first few feet increase in depth and then more slowly, approaching a relatively constant value. Consequently, for plates of ordinary size—that is, of areas say from 10 to 20 square feet—the depth in conducting soil should be from five to eight feet since greater depths would

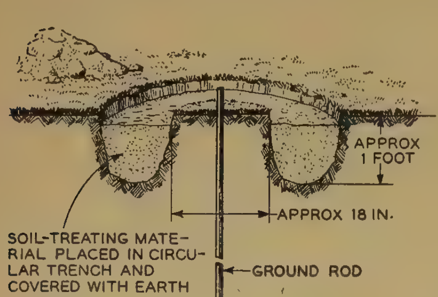


Figure 10. Trench method of soil treatment

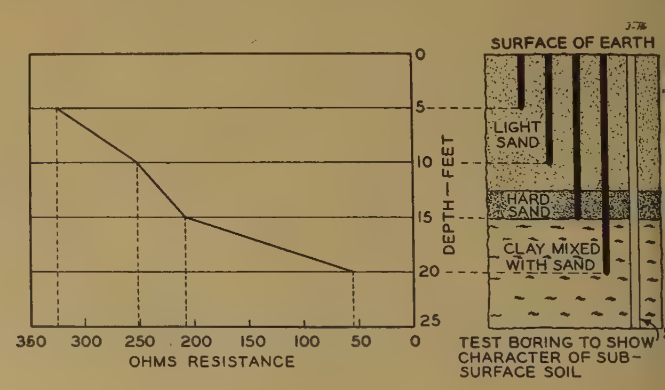


Figure 12. Deep grounds effective in lowering resistance

normally not show any appreciable decrease in resistance.

VARIATION OF RESISTANCE WITH AREA OF PLATE

The resistance of a plate ground is dependent upon the area of the plate, or more correctly stated, on the extent or over-all dimensions of the plate, since the volume of affected soil is the actual determining factor. The variation of resistance with the size of plate is illustrated in Figure 13. This curve is calculated for a circular plate assuming uniform soil resistivity.[4] It will be noted that quadrupling the area of such a plate approximately halves the resistance. This same relation holds approximately true for rectangular shape plates, although because of the nonhomogeneity of the soil, this should be taken only as an indication of the relationship mentioned and not as a check upon it. This curve also shows that increasing the area of a plate beyond 25 to 30 square feet does not result in an appreciable decrease in resistance. Consequently, where plate electrodes must be used, it would require much less labor and material to install two small plates at a distance from each other and connect them in multiple than to install one equivalent large plate.

BURIED STRIPS

Where bedrock is near the surface of the ground, it is frequently out of the question to drive electrodes or to dig deep enough to make an effective ground connection with plates. In such places, the ground is apt to be very dry, particularly during periods of drought, as the soil is not deep enough to permit the storage of moisture during wet seasons. The best procedure under such circumstances is to make a ground connection by burying narrow strips of metal, solid wire, or cable in trenches dug as deep as the rock layer will permit. Because of the high resistivity of the soil which is encountered in dry seasons, it is necessary to have a ground connection of considerable extent, and metal in the form of strips, wires or cables, offers the most efficient method.

VARIATION OF RESISTANCE WITH LENGTH

That an extensive length of metal is required for obtaining a ground connection with low resistance may be seen from the curve shown in Figure 14. This is a theoretical curve based on uniform soil resistivity.[4] Actual measurements which have been made are substantially in agreement with this curve allowing for inconsistencies in the resistivity of the soil existing at the particular location.

It appears from this curve that if the length of the strip is doubled, the resistance is approximately halved. This ratio assumes strips buried in a straight line. If the strips are curved or coiled, the resistance would tend to be higher as the affected soil would be less. With long leads, reactance is also a particularly important factor when dealing with lightning. Consequently, the use of a number of strips in parallel, but well spaced from each other, is usually preferable to one extra-long strip.

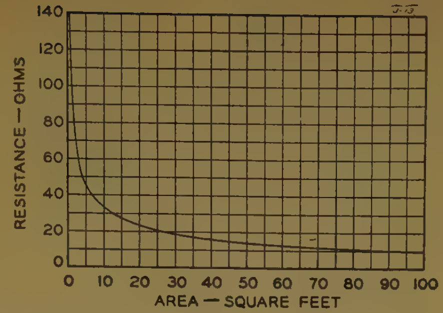


Figure 13. Variation of resistance of a circular plate with area, assuming uniform soil resistivity

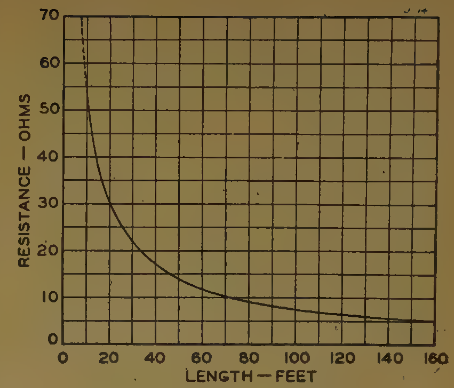


Figure 14. Variation in resistance of a strip electrode with length, assuming uniform soil resistivity

VARIATION OF RESISTANCE WITH DEPTH

Where bedrock exists near the surface of the ground, the depth at which the strip of metal can be buried is necessarily limited. However, where this is not the case and this type of ground is indicated, the relation between depth and resistance may be of interest. Tests by the Bureau of Standards show that the decrease in resistance for a variation in depth between the minimum permissible on account of cultivation—about 18 inches—and the maximum to which it would be practicable to bury an electrode—say three feet—is only about five per cent assuming uniform soil resistivity. Also, the effect of conductor size is extremely small within the range normally used for this purpose.[4]

GRIDS

Grid systems consisting of copper cables buried about six inches in the ground and forming a network of squares are sometimes used at generating plants or substations. The purpose of this grid is to provide equipotential areas throughout the entire station plot, thus avoiding any gaps where differences in potential would be hazardous to life and property.

Such a system usually extends over the entire station yard as well as some distance beyond the fence which surrounds the buildings and equipment. The spacings of the conductors, and therefore the size of the squares, will vary with the different installations. However, cable spacings of 10 to 12 feet have been used at some locations. All crossing points of the cables should be securely bonded together and the entire grid system tied in with the station ground. Also, all structural steel work and equipment are tied in with this network to prevent any differences in potential between these and the ground.

Protective systems of this type, as well as low-resistance grounds, are effective at stations because of the potential gradient which might otherwise result from high fault currents. The cost of installing such a grid system may be rather high because of the amount of labor involved, but the hazards to life and value of the property involved may justify such installations.

COUNTERPOISE

The counterpoise is used extensively in the United States for improving the lightning protection afforded by overhead ground wires on high-voltage transmission lines. This is an application of the buried-strip type of electrode, although round solid wires or stranded cables are generally used rather than strips.

Its usual application is in districts having high-resistance soils, such as sand or rock formation where a supplementary grounding system may be required. It is beneficial in reducing the impedance of the ground connection and in increasing the capacitance coupling with the conductors. It makes use of the widely distributed contact to the soil similar to a number of ground rods in parallel.

Two different arrangements of counterpoise wires have been employed, the continuous type and the radial type. The continuous counterpoise consists of a conductor or conductors buried under the transmission line from end to end of the line or at certain sections of the line and interconnected with the ground wire at all supporting structures. A method commonly used for installing such a counterpoise is by means of a cable-laying plow which places the wire in the ground at various depths down to as low as three feet beneath the surface.

The radial type of counterpoise consists of a number of wires extending radially from the grounding point. The number and length of the radial counterpoise wires will depend on the requirements at the particular location. Soil conditions, the importance of the line, and installation costs must all be considered in determining the extent of counterpoise installations.

Soil conditions along a transmission right of way may vary widely and one particular method of grounding may not be suitable for the entire line. A practical procedure is to make tests at each location

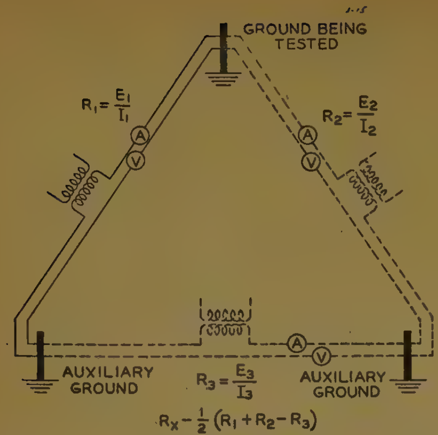


Figure 15. Connections for three-point method of measuring ground resistance, using a-c ammeter and voltmeter

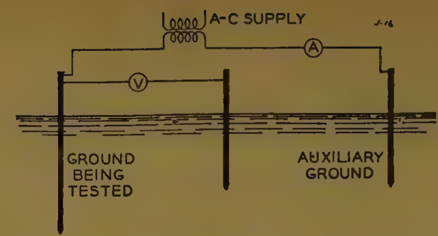


Figure 16. Connections for fall-of-potential method of measuring ground resistance

along the line and with the aid of the resistance data obtained, grounding methods can be selected which best suit the requirements. With this plan, low resistances can be obtained at the least cost.

METHODS OF MEASURING RESISTANCE OF GROUND CONNECTIONS

The proper operation of ground connections, like other electric equipment, is dependent largely on well planned testing and maintenance. The resistance of a ground connection should be measured at the time of installation and this should be followed by check tests at regular intervals. Usually precision in such measurement is not required, as it is necessary to know only whether the resistance is of the order of 1 ohm, 10 ohms, 100 ohms, or 1,000 ohms. These values are indicative of whether the ground is satisfactory for the particular installation or whether improvement is necessary.

There are various methods for testing the resistance to earth of installed ground connections. They are similar in that two independent auxiliary electrodes are used in addition to the one under test. These auxiliary electrodes should be placed at a distance remote enough from the ground under observation and from each other so that each ground is independent of any proximity effect of the other two grounds.[11]

The principles used in the measurement of ground resistances are essentially the same as those used for measuring other types of electrical resistances. However, for purposes of discussion, the various methods for measuring ground resistance have been grouped into three general classes which are described herewith.

THREE-POINT METHOD

With the commonly known three-point method, the resistances of the electrode under test and the auxiliary electrodes are measured two at a time in series. A voltmeter and an ammeter are used for making the measurements. Either alternating current of commercial frequency or direct current supplied from an available circuit or from a storage battery may be used. The diagram of connections shown in Figure 15 is applicable when using alternating current. The connections for direct current are similar, but certain precautions as explained later are required. After the three series measurements are made, the unknown resistance is solved by means of the formula

$$R_x = \frac{1}{2}(R_1 + R_2 - R_3)$$

A Wheatstone bridge operating on alternating current at 1,000 cycles per second and with a headphone as a detector to determine the point of balance is also applicable with the three-point method. Another method would be to use a direct-reading self-contained ohmmeter.

To obtain a fair degree of accuracy with the three-point method, the resistances of the auxiliary electrodes should be of the same order of magnitude as that of the unknown, otherwise small errors in the individual measurements may result in a large error in the computed resistance.

Stray direct currents have little or no effect on the readings when using alternating current. However, if stray alternating current of the same frequency as the test current is present, this may introduce an error.

When direct current is used for measurement purposes, the effect of stray alternating currents is eliminated and the effect of stray direct currents can be minimized by reversing the test current. Polarization is also a factor when direct current is used and the formation of gas at the electrodes may give a false indication. Taking two readings by reversing the current polarity helps to correct this condition. The current should be applied for short periods only, or just long enough to obtain the readings.

FALL-OF-POTENTIAL METHOD

Another method for measuring ground resistance is based on the fall-of-potential principle. This involves the passing of a known current through the electrode under observation and one of the auxiliary electrodes. The drop in potential between the former and the second auxiliary electrode is then measured and the ratio of this voltage drop to the known current will indicate the resistance to ground. The diagram of connections for this method using alternating current for test is shown in Figure 16. By using a voltage measuring device which has a high impedance, the resistance of the potential electrode will have no appreciable effect on the accuracy of the measurements. The determination of ground resistance by this method may be made with an ammeter and voltmeter or with self-contained instruments which are based on this principle and furnish direct readings of resistance.

RATIO METHOD

In a third method for measuring ground resistances, known as the ratio method, the series resistance of the electrode being tested and an auxiliary electrode is determined by means of a Wheatstone bridge. A slide-wire potentiometer is shunted across these two ground connections and the detector is connected between the sliding contact and the second auxiliary electrode. In this way, the ratio of the unknown resistance to the total resistance of the two electrodes in series is obtained and the required value is determined by multiplying this ratio by the series resistance obtained in the first measurement.

Measurements by this method may be made by using a bridge and a calibrated slide-wire potentiometer for obtaining the ratio, or by self-contained instruments which give direct readings.

PORTABLE GROUND-TESTING INSTRUMENTS

A portable ground-testing instrument provides the most convenient and satisfactory means for measuring the resistances of grounds. It is self-contained, easy to operate, and the resistance is indicated directly on a dial located on the panel of the instrument. The measurement is made with one setup and when desired the whole operation can be handled by one man. When any program of ground testing is planned, the use of one or more of these instruments is recommended, as the convenience and saving in labor will more than justify their cost.

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INSTITUTE ACTIVITIES

Official Nominees Announced for 1945–46

W. E. Wickenden, president, Case School of Applied Science, Cleveland, Ohio, was nominated for the AIEE presidency for the year 1945–46 by the national nominating committee at its meeting in New York, N. Y., January 23, 1945. Others named on the official ticket of candidates for the Institute offices that will become vacant August 1, 1945, are:

For Vice-Presidents

E. S. Fields, vice-president, Cincinnati (Ohio) Gas and Electric Company (Middle Eastern District, number 2).
H. B. Wolf, superintendent of maintenance, Duke Power Company, Charlotte, N. C. (Southern District, number 4).
L. M. Robertson, transmission and station engineer, Public Service Company of Colorado, Denver (North Central District, number 6).
F. F. Evenson, consulting engineer, San Diego, Calif. (Pacific District, number 8).
F. L. Lawton, assistant chief engineer, Aluminum Company of Canada, Montreal, Quebec (Canada District, number 10).

For Directors

J. M. Flanigen, distribution engineer, plant accounting, Georgia Power Company, Atlanta.
J. R. North, assistant electrical engineer, Commonwealth and Southern Corporation, Jackson, Mich.
W. C. Smith, engineer of Pacific District, General Electric Company, San Francisco, Calif.

For National Treasurer

W. I. Slichter, professor emeritus of electrical engineering, Columbia University, New York, N. Y.

The nominating committee, in accordance with the constitution and bylaws, consists of 15 members, one selected by the executive committee of each of the ten geographical Districts, and five selected by the board of directors from its own membership.

The constitution and bylaws of the Institute require publication in *Electrical Engineering* of the nominations made by the national nominating committee. Provision is made for independent nominations as indicated in the following excerpts from the constitution and bylaws:

Constitution

Section 31. Independent nominations may be made by a petition of twenty-five (25) or more members sent to the national secretary when and as provided in the bylaws; such petitions for the nomination of vice-presidents shall be signed only by members within the District covered.

Bylaws

Section 23. Petitions proposing the names of candidates as independent nominations for the various offices to be filled at the ensuing election, in accordance with article VI, section 31 (Constitution), must be received by the secretary of the National Nominating Committee not later than March 25 of each year, to be placed before that committee for the inclusion in the ballot of such candidates as are eligible.

On the ballot prepared by the national nominating committee in accordance with article VI of the Constitution and sent by the national secretary to all qualified voters during the first week in April of each year, the names of the candidates shall be grouped alphabetically under the name of the office for which each is a candidate.

BIOGRAPHICAL SKETCHES OF NOMINEES

To enable those Institute members not personally acquainted with the nominees to learn something about their engineering careers and their qualifications for the Institute offices to which they have been nominated, brief biographical sketches are scheduled for inclusion in the "Personal" columns of the March issue.

Buffalo and Detroit Technical Meetings Canceled

In compliance with the recently announced wartime ban on conventions, the AIEE board of directors has canceled the North Eastern District technical meeting scheduled to be held April 25–26, in Buffalo, N. Y., and the summer technical meeting scheduled for June 25–29 in Detroit, Mich. This action was taken at the regular meeting of the board held during the winter technical meeting in New York, N. Y., which was drawing to a close as this issue went to press.

The Institute's technical program and publication committees are planning to continue the publication of technical papers in *Electrical Engineering* and AIEE *Transactions* and are devising a plan whereby discussions may be submitted by mail. Details will be announced later.

Index Pamphlet for 1944 Delayed

The annual index to *Electrical Engineering* and *AIEE Transactions*, in recent years distributed as Section 2 of the February issue of *Electrical Engineering*, has not yet become available for material published in 1944 because of the time required for production of an unusually large *Transactions* volume. As a single index pamphlet covers both *Electrical Engineering* and *Transactions* it cannot be published until the *Transactions* is completed.

Approximately twice as many technical papers and discussions were approved for publication in the latter half of 1944 as in the same period of 1943, and the increased quantity of material together with other wartime difficulties has made impossible the maintenance of former production schedules.

SECTION • • • • •

AIEE Boston Section Expands Technical Groups

On the basis that the individual member can derive much value from the discussion and question type of meeting of a small interested group, the incoming AIEE Boston Section executive committee for 1944–45 has announced its decision to expand the technical groups to include four basic subjects for the coming year. These groups, with their chairmen, are: electronics, T. S. Gray, Massachusetts Institute of Technology; electrical machinery, F. B. Haeussler, General Electric Company; insulation, W. I. Middleton, Simplex Wire and Cable Company; and transmission and distribution, J. F. Archibald, Boston Edison Company. Ex-officio members of the technical group committee are: chairman of Section, A. L. O'Banion; secretary-treasurer, R. E. Muehlig; and chairman of meetings committee, C. T. Burke. R. G. Porter, Northeastern University, Boston, Mass., will act as general chairman.

The Boston Section executive committee and membership had felt for some time that the regular meetings of the Section were, in general, of such a nature that they did not offer a large enough concentration in the technical field for the various groups composing the membership of a large section. On this assumption, two meetings of a technical group composed of men in the insulation field were held in 1944. The success of these meetings prompted the formation of the four new groups with a 1944–45 program consisting of three meetings for each group, the chairman of each group to organize his own committee and act as chairman of any meetings of his group.

Experience so far with the new technical groups is that, rather than distracting from the regular monthly Boston Section meetings, they have stimulated interest in the Section, and that the attendance at regular meetings has increased. The meetings have demonstrated that for a large Section the maximum value for its membership can be secured by offering a program which includes ample participation in discussion by its members.

PERSONAL • • • •

Zay Jeffries (M '36, F '42) formerly technical director of the lamp division of the General Electric Company has been elected a vice-president in charge of the recently organized chemical department. Doctor Jeffries received the degrees of bachelor of science in mining engineering in 1910 and metallurgical engineer in 1914 from the South Dakota School of Mines and earned the degree of doctor of science from Harvard University in 1918. Doctor Jeffries, who also has been professor of the Case School of Applied Science and consultant for the Aluminum Company of America, joined the General Electric Company in 1914 and was made technical director of the lamp division in 1936. He has been honored with several degrees and medals and is a member of numerous scientific societies. **E. O. Shreve** (A '06) vice-president and chairman of the apparatus operating committee of the General Electric Company, Schenectady, N. Y., has relinquished these duties to become a member of the president's staff in charge of customer relations in New York, N. Y. Mr. Shreve was manager of the company's industrial engineering department from 1926 until he became vice-president in 1934. **R. C. Muir** (A '08, F '36) formerly a vice-president of the executive staff of the company in Schenectady has been made general manager of the apparatus department. Mr. Muir has

been with the company since 1905, except from 1919 to 1922, during which time he was chief commercial engineer of the International General Electric Company. He was appointed assistant to the vice-president in charge of engineering in 1930, manager of the engineering department in 1933, and vice-president in 1934. **Richard Cutts, Jr.** (A '29) formerly meter specialist, Boston, Mass., has been appointed manager of sales of the meter section, West Lynn, Mass. Mr. Cutts was meter specialist for the company's New York district from 1929 to 1937 when he was transferred to Boston. He is chairman of the watthour-meter and demand-meter management committee. **E. J. Boland** (A '29, M '36) of the meter division of the central-station engineering department Lynn, Mass., has been named manager of sales of the aircraft-instrument section. Mr. Boland, a member of the General Electric staff since his arrival in the United States from Denmark in 1926, has been assigned to aircraft-instrument work since the beginning of the war. **H. V. Erben** (M '43) vice-president and manager of the central-station department, has been named assistant general manager of the apparatus department. Mr. Erben has been with the General Electric Company since 1920 and has been manager of the central-station engineering department since 1941. **H. A. Winne** (A'16 M'39) vice-president, has been made manager of engineering for the apparatus department. **D. C. Prince** (A '16, F '26) vice-president, formerly in charge of application engineering, has been given charge of the company's general engineering laboratory. Associated with the General Electric Company since 1914, Mr. Prince has been, in the course of his career, a member of the research laboratory staff, research engineer on switchgears, and manager of commercial engineering. **C. G. Suits** (M '41) formerly assistant to the director of the research laboratory, has been elected a vice-president and appointed director of the research laboratory. Doctor Suits, who graduated from the University of Wisconsin in 1927, has been a member of the laboratory staff since 1930. He became assistant to the director in 1940. Since the war he has devoted his time to war research under the direction of the Office of Scientific Research and Development.

P. C. Smith (A '26) electrical engineer assigned to special work at the New Philadelphia, Ohio, plant of the Westinghouse Electric and Manufacturing Company, has been appointed assistant to the manager of the transportation and generator division, East Pittsburgh, Pa. **J. S. Askey** (A '39) coil and insulation design engineer, and **G. L. Moses** (A '43) insulation development engineer, have been made section engineers in the transportation and generator division.

M. A. Princi (A '36) formerly in charge of experimental testing and special test equipment, General Electric Company, West Lynn, Mass., has been named assistant designing engineer of the aeronautical-instrument engineering division, in charge of the gyroscope section. **R. G. Ballard** (A '42) formerly instrument engineer, has been appointed assistant designing engineer of the aircraft-instrument engineering division, in charge of the general instrument section.

F. E. Terman (A '23, M '34) head of the Government's radio research laboratory, Cambridge, Mass., has been appointed dean of the school of engineering of Stanford University, Calif. Professor Terman received the bachelor of arts degree from Stanford University in 1920, the engineering degree in 1922, and the degree of doctor of science from Massachusetts Institute of Technology in 1924. He joined the Stanford University faculty in 1925 as an instructor, becoming assistant professor in 1927, associate professor in 1930, and professor and head of the electrical-engineering department in 1937. He obtained a leave of absence from this position in 1942 to head the radio research laboratory in Cambridge. He is a member of Phi Beta Kappa and Sigma Xi and a past president of the Institute of Radio Engineers.

R. R. Stoddard (A '38) formerly power engineer, the Philadelphia (Pa.) Electric Company has been appointed industrial engineer for the Fitchburg (Mass.) Gas and Electric Company, the Rockland (N. Y.) Light and Power Company, the Concord (N. H.) Electric Company, the Exeter and Hampton (N. H.) Electric Company, and various other utilities. Mr. Stoddard's headquarters will be at Boston, Mass.

J. W. Sanger (M '42) formerly chief engineer, City of Winnipeg (Manitoba, Canada) Hydro-Electric System has been made manager of the system. Mr. Sanger's early experience was as district engineer, Midland Electric Power Corporation, Staffordshire, England, in 1906. He became associated with the Winnipeg Hydro-Electric System in 1912 as an engineer. He has been chief engineer since 1922.

H. C. Starkweather (M '38) senior electrical engineer, Signal Office, Third Service Command, Baltimore, Md., has been presented with a "Meritorious Service Award" citing him for his efforts in the field of signal communication. The certificate was awarded by Major General Philip Hayes and is signed by Lieutenant General Brehon Somervell and General Hayes.

B. K. Titter (A '32, M '43) formerly chief electrical engineer, the Nicaro Nickel Company, New York, N. Y., has been commissioned a lieutenant in the United States Naval Reserve. Lieutenant Titter had previously received instruction in radar at Brunswick, Me., and Boston, Mass., and is now assigned to radar duties.

W. M. Shober (A '22, M '40) formerly electrical engineer, Aluminum Company of America, located at Alcoa, Tenn., and Burlington, N. J., is now associated with the Allis-Chalmers Manufacturing Company, Milwaukee, Wis., in the electrical department, mixed apparatus division.

W. E. Ross (M '38) manager of the apparatus sales department, the Canadian General Electric Company, Ltd., Toronto, Ontario, Canada, has been appointed Ontario Government representative on the electrical branch of the Association of Professional Engineers of Ontario by the lieutenant-governor-in council.

William Fondiller (M '15, F '26) electrical apparatus director, Bell Telephone Laboratories, Inc., New York, N. Y., has been announced as the recipient of the Townsend Harris Medal for postgraduate achievement awarded annually by the College of the City of New York to an outstanding graduate.

H. A. Moench (A '31, M '38) has been promoted to the rank of major in the Signal Corps of the United States Army. Commissioned a second lieutenant in the Corps of Engineers Reserve in 1929, he was called to active duty with the Signal Corps in 1942.

W. J. Cherones (A '43) formerly chief civilian engineer, central station fire control and computing gunsights department, Army Air Forces Headquarters, Dayton, Ohio, has been appointed instrument engineer for the Roller-Smith Company, Bethlehem, Pa.

H. B. Marvin (A '20, M '43) formerly assistant engineer, general engineering laboratory, General Electric Company, Schenectady, N. Y., will be responsible for special assignments in the tube division, electronics department.

L. M. Smith (M '36) formerly chief electrical engineer, Alabama Power Company, Birmingham, has been appointed director of public relations for that company. Mr. Smith has been with the Alabama Power Company for the past 21 years.

O. W. Eshbach (A '17, F '37) dean of engineering, Northwestern Technological Institute, Evanston, Ill., has been elected chairman of the 1945 Washington Award Commission of the Western Society of Engineers, Chicago, Ill.

L. A. Rebsamen (A '31) manager of the city water and light plant, Jonesboro, Ark., has resigned to go into private business.

OBITUARY ....

Paul Martyn Lincoln (A '95, M '98, F '12) president of the Therm-Electric Meter Company, Ithaca, N. Y., and professor emeritus and former director of the school of electrical engineering, Cornell University, died December 20, 1944. He was born in Norwood, Mich., January 1, 1870, and was educated at Western Reserve and at Ohio State universities, receiving from the latter the degree of mechanical engineer in electrical engineering in 1892. He was employed first as testing electrician by the Brush Electric Company, doing some drafting later. The next year, in 1893, he went to the Pittsburgh, Pa., plant of the Westinghouse Electric and Manufacturing Company, where he took the training course of the company. In 1895 he was chosen for the position of electrical superintendent in charge of water power development at Niagara Falls., N. Y., with the Niagara Falls Power Company. Hydroelectric development was in the early stages then, and the amount of power generated, transmitted, and distributed by this first plant was so far in excess of anything accomplished up

to that date that it was unique; Mr. Lincoln's responsibilities were considerable as he had charge of the operating department. In 1902 he returned to the Westinghouse Company in Pittsburgh and was in charge of the power division of the engineering department for six years. He was appointed general engineer for the company in 1910, holding that position until 1919. At that time he resigned from his position with the Westinghouse Company to join the firm of his older brother, the Lincoln Electric Company, as consulting engineer. From 1911 to 1915 he was head of the electrical school at the University of Pittsburgh, and in 1922 became director of the school of electrical engineering at Cornell University. He became professor emeritus in 1938, and in the same year became president of the Therm-Electric Meter Company. In 1902 he was the recipient of the John Scott Medal of the City of Philadelphia for his invention of the synchroscope. The honorary degree of doctor of engineering was conferred upon him in 1933 by Ohio State University. Professor Lincoln served the Institute as manager (1906–09), as vice-president (1909–11), and as president (1914–15). He was active on Institute committees, serving on the papers, and meeting and papers (now technical program) committees, on the executive, Sections, and law committees, and on many technical committees, including power stations, protective devices, transmission and distribution, electrical machinery, Standards, and instruments and measurements. He served on the board of award of the John Fritz Medal, and on the Edison and Lamme Medal committees. He was a member of the board of management of the World's Congress of Engineers, 1923–25, and was a member of several scientific and engineering societies in the United States.

Paul Milton Downing (A '98, M '08, F '42) executive vice-president of the Pacific Gas and Electric Company, San Francisco, Calif., died December 11, 1944. Mr. Downing was born in Newark, Mo., November 27, 1873, and was graduated from Stanford University in 1895 with the first graduating class. Before entering upon his lifetime association with the Pacific Gas and Electric Company, he was employed by several other power companies, the Tacoma (Wash.) Light and Power Company, the Market Street Railway Company, San Francisco, the Standard Consolidated Mining Company (three companies which later merged with the Pacific Gas and Electric Company), and by the Colusa Gas and Electric Company, the Bay Counties Power Company, and the California Gas and Electric Company. When the Pacific Gas and Electric Company was formed by merger in 1908, he became engineer of maintenance and operation. He was made chief engineer in 1917, vice-president in charge of electrical construction and operation in 1920, vice-president and general manager in 1929, and executive vice-president in 1943. One of his latest accomplishments in this position was the completion of Pit 5 hydroelectric station in Shasta County, Calif., the largest installation of its kind in that state. Mr. Downing was an AIEE vice-president from 1925 to 1927, a vice-president of the Edison Electric Institute, and a past president of the Pacific Coast Electrical Association.

Herbert Stead Sands (A '06, M '13) consulting engineer and president of the Denver Board of Water Commissioners, died December 13, 1944. He was born in Stamford, Conn., July 27, 1874, and was student engineer with the Edison General Electric Company from 1889 to 1894. He was superintendent for the Baltic (Conn.) Power Company from 1893 to 1899, for the Cripple Creek District Railway in 1899, and for La Bella Mill, Water, and Power Company, Goldfield, Colo., from 1899 to 1901. From 1901 to 1905 he was associated with the Seaton Mountain Electric Light and Power Company, Idaho Springs, Colo. Mr. Sands was manager of the industrial division of the Westinghouse Electric and Manufacturing Company, Denver, Colo., from 1905 until his retirement to private practice in 1927. Active in civic affairs, Mr. Sands was president of the Denver Chamber of Commerce from 1929 to 1932 and in 1932 was voted an honorary life membership in that body. He was a member of the board of directors of the Public Service Company of Colorado and president of the State Board of Engineering Examiners. He was a member of the Colorado Engineering Council and its president from 1925 to 1927. He was made an honorary member of the Colorado University chapter of Tau Beta Pi and received the degree of electrical engineer from that institution in 1926. He was a director of the Home Loan Bank of Topeka and a member of the Colorado Scientific Society.

Joseph Arthur Jeffery (M '20) vice-president of the Champion Spark Plug Company and general manager of its ceramic division in Detroit, Mich., died December 26, 1944. Doctor Jeffery, who was born in San Francisco, Calif., in 1873, was graduated from the University of California with a degree in dentistry in 1895. From 1897 to 1900 he was instructor in chemistry and metallurgy at the University of California. While he was practicing dental surgery in San Francisco, his interest in dental porcelains broadened to ceramics in general. Experiments with synthetic sillimanite led him to a search for natural deposits worthy of commercial exploitation. In 1918 he discovered such deposits in the Inyo range in California and thereupon founded the Jeffery-Dewitt Company and the Jeffery-Dewitt Insulator Company of which he became president. These companies were merged with the Champion Spark Plug Company in 1921. Doctor Jeffery also was president of the Champion Sillimanite, Inc., of California and Nevada, a subsidiary of the parent company. He was a member of the American Ceramic Society, the Electrochemical Society, the American Institute of Mining and Metallurgical Engineers, and the Detroit Engineering Society.

William Lawrence Tadlock (A '29, M '37) supervising electrical distribution engineer, Commonwealth and Southern Corporation, Birmingham, Ala., died November 27, 1944. Born in Talbott, Tenn., March 11, 1902, he was graduated from the Carnegie Institute of Technology with the degree of bachelor of science in electrical engineering in 1924. In 1924 and 1925 he worked on radio research for the General Electric Company, Schenectady, N. Y., and in 1925 established his own radio-broadcasting receiver service in Knoxville, Tenn. From 1926 to 1930 he was distribution engineer with what is now the Tennessee Public Service Company. In 1930 he joined the Allied Engineers, Inc., in Atlanta, Ga., which was later absorbed by the Commonwealth and Southern Corporation, and worked on the design and construction of underground distribution systems. In this position he planned expanded distribution systems for the cities of Nashville and Chattanooga, Tenn. He was employed as engineer in the Navy Yard expansion at Pearl Harbor in the Hawaiian Islands from 1934 to 1936. In 1936 he returned to the United States to become supervising engineer for the Commonwealth and Southern Corporation. Mr. Tadlock was author of the article, "Evaluation of Incompletely Diversified Loads," published in the November 1943 issue of *Electrical Engineering*.

Leon Walter Rosenthal (A '02, M '13, F '19) engineer, inventer, and patent soliciter, New York, N. Y., died January 8, 1945. Mr. Rosenthal was born August 9, 1880, in Marlin, Tex., and was graduated from Columbia University with the degree of electrical engineer in 1902. He was assistant to George H. Sever, consulting engineer, and professor of electrical engineering at Columbia University, New York, until 1903 when he joined the New York Central and Hudson River Railroad to work on the electrification of its New York zone. In 1909 he went to Guatemala to design and lay out an electric railway for that country. Returning to New York in 1910 he joined the patent-attorney firm of Pennie, Davis, Marvin, and Edmonds with which he remained until 1918 when he was retained by the Alien Property Custodian as patent counsel for the Bosch Magneto Company. In 1919 he became vice-president of the American Bosch Magneto Corporation, and in 1934 he opened a private patent practice. Mr. Rosenthal held a number of patents in his own right and was the author of several books, including "Calculation of Electrical Transmission Lines" and "Arnheim and Multiplex Slide Rules." He was a member of the Society of Automotive Engineers and the Radio Club of America.

Alf Hjort (M '21) chief engineer, George H. Flinn Corporation, New York, N. Y., died December 12, 1944. Born October 12, 1877, in Oslo, Norway, Mr. Hjort was graduated from the Technical College of Hanover, Germany. He worked in Berlin, Germany, in the testing department of the Bergman Electric Company in 1902 and in the calculating department of the General Electric Company in 1903. After coming to the United States he was employed by S. Pearson and Sons, contractors, on the Pennsylvania Railroad East River tunnels from 1904 to 1909. He was electrical engineer in charge of the New York City aqueduct for the Degnon Contracting Company from 1909 to 1911. In 1911 he joined the Flinn Corporation, then known as Booth and Flinn, Ltd., and in 1929 became chief engineer for the corporation. Throughout this association he worked on many tunnel and sewer projects in the New York area. Mr Hjort was a member of the American Society

of Municipal Engineers and the American Society of Military Engineers.

William Lord Bliss (A '94, F '17) consulting engineer, USL Battery Corporation, Niagara Falls, N. Y., died December 5, 1944. Mr. Bliss was born July 16, 1871, in Brooklyn, N. Y., and received the degree of bachelor of science in electrical engineering from the Polytechnic Institute of Brooklyn in 1891 and the degree of master of mechanical engineering from Cornell University in 1893. He developed his lifelong interest in car-lighting apparatus during early employment with the Riker Electric Motor Company, Brooklyn, N. Y., in 1893 and with the Consolidated Gas Company, New York, N. Y. From 1897 to 1901 he engaged in private research on the subject and in 1901 he formed the Bliss Electric Car Lighting Company of New Jersey. When this company was consolidated into the United States Light and Heating Company, Mr. Bliss was made chief engineer, and he continued in that position with its successor the USL Battery Corporation. He retired to the position of consulting engineer in 1941. He was the holder of numerous patents.

Francis Wymond Hurlbert (A '04) retired electrical sales engineer of the International General Electric Company, New York, N. Y., died December 4, 1944. Born in Aurora, Ind., June 3, 1870, Mr. Hurlbert was graduated from Rose Polytechnic Institute in 1891 with the degree of bachelor of science in electrical engineering. His early career was concerned with railway engineering for the Detroit Street Railways; the Brush Electric Company, Cleveland, Ohio; and in the railway-engineering department of the General Electric Company, Schenectady, N. Y. In 1902 he entered the foreign department of the latter company and in this connection was sent to Mexico. Upon his return he entered the sales department and later was transferred to the New York, N. Y., office of the foreign department, which eventually became the International General Electric Company. In 1901 Mr. Hurlbert had charge of the General Electric Company exhibit at the Pan American Exposition in Buffalo, N. Y.

Leroy Coffin (A '37, M '41) electrical engineer, Bureau of Ships, Washington, D. C., died November 16, 1944. Born June 8, 1899, in Carlos City, Ind., Mr. Coffin was graduated from Purdue University with the degree of bachelor of science in electrical engineering in 1923. He was associated with the Allis-Chalmers Manufacturing Company, Milwaukee, Wis., from 1923 to 1941 as student engineer; special investigator on telephone problems; designer of induction motors, turboalternators, and other equipment; and writer of instruction books. From 1928 to 1934 he was instructor in the evening session of the Milwaukee Vocational School. In 1940 he was loaned to the Bureau of Ships where he was regarded as an outstanding authority on electric ship propulsion. He was one of the key figures in the repair of the battleships sunk or damaged at Pearl Harbor in 1941.

Theodore Schou (M '14) consulting engineer, Fairbanks, Morse, and Company, Beloit, Wis., died November 16, 1944. Born in Förde, Norway, on March 23, 1879, Mr. Schou was graduated from the Royal Academy of Kristiana, Norway, in 1897. He came to the United States in 1903 and in 1904 entered the employ of Westinghouse, Church, Kerr, and Company, New York, N. Y. Ensuing positions included designing engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., in 1911; professor at the State University of Iowa, Iowa City, in 1916; and chief engineer, the Ideal Electric and Manufacturing Company, Mansfield, Ohio, in 1920. He joined Fairbanks, Morse, and Company in 1928 as chief electrical engineer. Mr. Schou was the author of numerous articles for technical magazines.

Theodore Varney (A '05) an electrical engineer of New York, N. Y., died October 2, 1944. On January 27, 1875, Mr. Varney was born in Fort Leavenworth, Kans., and in 1894 he was graduated from the Massachusetts Institute of Technology. In 1901 he was with the Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa.; in 1913 with the Commonwealth Electric and Supply Company, and in 1915 with the Aluminum Company of America, both of Pittsburgh. In 1928 Mr. Varney was a consulting engineer for Aluminum Ltd. of New York, N. Y., and in 1935 he went to Aluminum Ltd., of Montreal, Quebec, Canada. Mr. Varney returned to the United States in1939.

Thomas R. Crumley (A '19) president, Jersey Central Power and Light Company, Asbury Park, N. J., died October 5, 1944. Mr. Crumley was born in Wayne, Pa., on September 20, 1878. He began his career in 1901 in the testing and engineering department, General Electric Company, Schenectady, N. Y. He was engaged in transportation work from 1910 to 1915 as superintendent of motive power, Evansville (Ind.) Railways Company. In 1915 he became chief engineer for the Engineering and Management Corporation, New York, N. Y., and in 1921, president. Mr. Crumley became president of the Jersey Central Power and Light Company in 1928.

Frank A. Teach (A '24, M '29) relay engineer, Columbus and Southern Ohio Electric Company, Columbus, Ohio, died October 25, 1944. Born on August 8, 1892, in Pleasant Hill, Ohio, Mr. Teach was graduated in 1921 from Ohio State University and received the master of arts degree in 1938. During the first World War he was a lieutenant in the Signal Corps of the United States Army. In 1921 he was superintendent of construction for the State Highway Department of the State of Ohio and from 1923 to 1928 he was electrical engineer and inspector for the Department of Buildings, Columbus. Subsequently, Mr. Teach was with Gustave Hirsch, consulting engineer of Columbus, and the Columbus Railway, Power and Light Company. He joined the Columbus and Southern Ohio Electric Company in 1937. He was a member of the State Board of Registration of Professional Engineers and Surveyors.

Willard L. Newman (M '35) equipment cost engineer, long-lines department, American Telephone and Telegraph Company, New York, N. Y., died October 31, 1944. M Newman was born in Blairstown, N. J., o April 8, 1888, and was a graduate of Lehig University (1912). His entire profession career was spent in the long-lines departme of the American Telephone and Telegrap Company, which he entered in 1912 i Buffalo, N. Y., where his work consisted maintaining central-office telephone an telegraph equipment. After holding variou other positions with the company, M Newman was made equipment cost enginee in 1941.

Charles G. Atkins (A '01, M '21) consultin engineer, Chicago, Ill., died October 2 1944. Born on February 16, 1865, in Tiffin Ohio, Mr. Atkins was a graduate of the Uni versity of Michigan (1893). Following hi graduation, Mr. Atkins became assistant t the chief engineer of tests and constructin work on roads, Westinghouse Electric an Manufacturing Company. In 1896 h entered the employ of the Chicago (Ill. Edison Company in the engineering depart ment. Mr. Atkins had been a consultin engineer since 1901. He was a member o the Western Society of Engineers.

MEMBERSHIP • •

Recommended for Transfer

The board of examiners, at its meeting on January 18 1945, recommended the following members for transfe to the grade of membership indicated. Any objection to these transfers should be filed at once with the nationa secretary.

To Grade of Fellow

Angus, D. J., president and chief engr., Esterline-Angu Co., Indianapolis, Ind.
Bosch, L. L., chief, Equipment Production Branch WPB, Washington, D. C.
Sah, A. P. T., president, National University of Amoy Changting, Fukien, China; at present M.I.T.

3 to grade of Fellow

To Grade of Member

Arenberg, A. L., president, Luminator Inc., Chicago, Ill.
Batten, W. B., section engr., Westinghouse E. & M. Co., E. Pittsburgh, Pa.
Brown, A. D., district mgr., Allis-Chalmers Mfg. Co., Los Angeles, Calif.
Caswell, R. W., senior engr., Public Service Co. o Northern Illinois, Chicago, Ill.
Catherwood, T. E. D., chief electrician, Buffalo Ankerite Gold Mines, Ltd., So. Porcupine, Ont., Can.
Collins, R. K., district elec. engr., Westinghouse E. & M Co., Los Angeles, Calif.
Cox, J. H., section engr., Westinghouse E. & M. Co., E. Pittsburgh, Pa.
Crippen, M. E., engr., U. S. Engineer Office, Little Rock, Ark.
Easley, G. J., design engr., Westinghouse E. & M. Co., E. Pittsburgh, Pa.
Herring, H. C., exchange engr., Southwestern Bell Tel. Co., Beaumont, Texas.
Hewitt, G. W., research engr., Westinghouse E. & M. Co., E. Pittsburgh, Pa.
Hollingshead, E. C., design engr., Westinghouse E. & M. Co., Sharon, Pa.
House, H. E., elec. engr., Aluminum Co. of America, Alcoa, Tenn.
Kelley, J. R., engr. of underground distribution, Dept. of Water and Power, Los Angeles, Calif.
Lieberkind, H. E., elec. engg. draftsman, West Penn Power Co., Pittsburgh, Pa.
Marshall, L. E., engr., Knoxville Elec. Pwr. & Water Board, Knoxville, Tenn.
Mentzer, R. D., test engr., Willamette Iron & Steel Co., Portland, Oreg.
Nichols, W. A., plant engr., Canadian Broadcasting Corp., Montreal, Can.
Nimmer, F. W., general distribution engr., Ohio Edison Co., Akron, Ohio
Oerman, H. W., underground engr., Public Service Co. of Northern Illinois, Chicago, Ill.
Pakala, W. E., design engr., Westinghouse E. & M. Co., E. Pittsburgh, Pa.
Parker, J. C., supervisor, Memphis Light, Gas & Water Div., Memphis, Tenn.
Pollard, E. I., design engr., Westinghouse E. & M. Co., E. Pittsburgh, Pa.
Schrameck, J. E., elec. engr., Westinghouse E. & M. Co., E. Pittsburgh, Pa.
Sellke, F. A., draftsman, West Penn Power Co., Pittsburgh, Pa.
Stewart, V. N., design engr., General Elec. Co., Philadelphia, Pa.

traube, A. W., plant engr., Daugherty Refinery, Petrolia, Pa.
utton, C. E., transformer specialist, General Elec. Co., Philadelphia, Pa.
hrasher, M. J., elec. engr., Texas Power & Light Co., Dallas, Texas.
innerholm, R. F., mgr., switchgear div., General Elec. Co., Philadelphia, Pa.
Vatson, P. R., asst. materials and processes engr., Curtiss-Wright Corp., St. Louis, Mo.
Voods, C. A., design engr., Westinghouse E. & M. Co., E. Pittsburgh, Pa.
Voodward, B. W., development engr., Remington Rand, Inc., Tonawanda, N. Y.

3 to grade of Member

Applications for Election

Applications have been received at headquarters from he following candidates for election to membership in he Institute. Any member objection to the election of ny of these candidates should so inform the national ecretary before February 28, 1945, or April 30, 1945, the applicant resides outside of the United States or anada.

To Grade of Member

nspach, R. J., Amer. Tel. & Tel. Co., New York, N. Y.
uehler, C. M., Taylor Inst. Cos., Rochester, N. Y.
avis, H. P., Ohio Bell Tel. Co., Akron, Ohio.
eBever, O. J., Expediters, Ltd., San Francisco, Calif.
echovitz, J., Sou. Bell Tel. & Tel. Co., Atlanta, Ga.
eloney, H. L., La. Pr. & Lt. Co., New Orleans, La.
oerr, C. G., Northern Ind. Pub. Serv. Co., Plymouth, Ind.
ouglas, P. W., Chrysler Corp., Chicago, Ill.
raper, R. O., Gen. Cable Corp., Perth Amboy, N. J.
uke, C. A., Tenn. Valley Auth., Chattanooga, Tenn.
riar, E. M., Carolina Tel. & Tel. Co., Tarboro, N. C.
oodell, S. E., Commonwealth Edison Co., Chicago, Ill.
lanley, E. L. (Reelection), Wis. Tel. Co., Milwaukee, Wis.
layes, J. H., Thirlwell, Henderson, Marine Elec. Co., Evansville, Ind.
lemperly, J. H., Willamette Iron & Steel Corp., Portland, Oreg.
lenry, L. W., Shell Oil Co., Inc., Wood River, Ill.
erstein, C. L., Rosenblatt & Hunt, Inc., Charleston, W. Va.
arson, N. G. (Reelection), Commonwealth Edison Co., Chicago, Ill.
ehr, C. N., Monitor Cont. Co., Baltimore, Md.
ewis, R. P., Westinghouse Elec. & Mfg. Co., Boston, Mass.
latthews, C. L. (Reelection), Brockway Land & Water Co., Brockway, Calif.
lcElwee, J. M. (Reelection), Chicago Dist. Elec. Gen. Corp., Hammond, Ind.
liller, H. C., E. I. du Pont de Nemours & Co., Wilmington, Del.
arillo, L., Hercules Powder Co., Wilmington, Del.
reston, A. S., Tenn. Eastman Corp., Oak Ridge, Tenn.
riest, C. A. (Reelection), General Elec. Co., Syracuse, N. Y.
andall, H. J., Dunlop Rubber Co. Ltd., Birmingham, England.
iley, L. G. (Reelection), Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
haw, W. R., Major, G.H.Q.(I), New Delhi, India.
egel, J. P. (Reelection), Commonwealth Edison Co., Chicago, Ill.
huem, C. H. (Reelection), George G. Sharp, New York, N. Y.
Vatson, G. O., Lloyd's Reg. of Shipping, London, England.
Villiamson, G. L., Gibson Elec. Co., Pittsburgh, Pa.

3 to grade of Member

To Grade of Associate

nited States and Canada

. North Eastern

limansky, M. I. (Reelection), Gen. Elec. Co., Pittsfield, Mass.
igsby, O. S. (Reelection), Central N. Y. Pr. Corp., Syracuse, N. Y.
lakeslee, G. T., 1st Lieut., U. S. Army, Horseheads, N. Y.
oughter, C. L., N. Y. State Elec. & Gas Corp., Binghamton, N. Y.
rightman, F. P., Gen. Elec. Co., Schenectady, N. Y.
urns, F. J., Jr., Eastman Kodak Co., Rochester, N. Y.
orea, E. V., U. S. Naval Dry Dock, South Boston, Mass.
aw, A. H., Buffalo Niag. Elec. Corp., Buffalo, N. Y.
olt, F. H. (Reelection), Gen. Elec. Co., Schenectady, N. Y.
umpage, H. A., Fed. Elec. Prod. Co., Inc., Hartford, Conn.
ylwa, L., Sylvania Elec. Prod., Inc., Danvers, Mass.
ohnson, R. R., Gen. Elec. Co., Schenectady, N. Y.
ing, C. W. (Reelection), Allis-Chalmers Mfg. Co., Buffalo, N. Y.
ibrock, G. E., Remington-Rand, Inc., Tonawanda, N. Y.
lyers, M. G., Jr., Westinghouse Elec. & Mfg. Co., Boston, Mass.
ama, F. W., American Steel & Wire Co., Worcester, Mass.
mpson, R. E., Westinghouse Elec. & Mfg. Co., Boston, Mass.
tanton, W. H., N. Y. State Elec. & Gas Corp., Ithaca, N. Y.
Stiehl, P. L. E., Lewis Engg. Co., Naugatuck, Conn.
Stockwell, S. W., Davis Transformer Co., Concord, N. H.
Switzer, D. C., N. Y. State Elec. & Gas Corp., Geneva, N. Y.

2. Middle Eastern

Ash, W. J., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Bean, W. E., Westinghouse Elec. & Mfg. Co., Huntington, W. Va.
Bovier, R. F., Northern Penna. Pr. Co., Towanda, Pa.
Canning, R., Pittsburgh Plate Glass Co., Creighton, Pa.
Chambers, W. L., Charleston Elec. Supply Co., Charleston, W. Va.
Dawson, G. G., Westinghouse Elec. & Mfg. Co., Charleston, W. Va.
Foschia, L. J., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Givner, S., Allis-Chalmers Mfg. Co., Norwood, Ohio.
Gordon, M. K., Jr. (Reelection), Bendix Avia. Corp., Philadelphia, Pa.
Haring, R., N. Y. Shipbldg. Corp., Camden, N. J.
Hufton, R. V., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Jacoby, W., I.T.E. Circuit Breaker Co., Philadelphia, Pa.
Kent, H. B., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Lindsey, H. L., Charleston Elec. Supply Co., Charleston, W. Va.
McCabe, E. F., Lieut., U. S. Army Air Forces, Dayton, Ohio.
McCloskey, W. J., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Melhorn, N. R., Jr., Radio Corp. of America, Lancaster, Pa.
Mills, C. E., U. S. Rubber Co., Institute, W. Va.
Nevin, R. A., Leland Elec. Co., Dayton, Ohio.
Noel, E. B., General Elec. Co., Cleveland, Ohio.
Orme, L. L., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Ransford, H. E. (Reelection), H. E. Ransford Co., Pittsburgh, Pa.
Richards, H. M., Virginian Elec., Inc., Charleston, W. Va.
Riedel, G. B., Scranton Elec. Co., Scranton, Pa.
Shipka, A. F., Leece-Neville Co., Cleveland, Ohio.
Spackman, A. L., British Overseas Airways, Baltimore, Md.
Timpe, N. B., Phila. Elec. Co., Philadelphia, Pa.
Vance, W. W., Toledo Scale Co., Toledo, Ohio.
Vogt, S. H., Westinghouse Elec. & Mfg. Co., Lima, Ohio
Williams, M., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Wise, B. L. (Reelection), Fed. Mach. & Welder Co., Warren, Ohio.

3. New York City

Grandin, F., Alan-Wood Steel Co., Ringwood, N. J.
Hawes, C. W., Fed. Tel. & Radio Corp., Newark, N. J.
Hoyer, E. W., Weston Elec. Inst. Corp., Newark, N. J.
Johnson, C. W., Philco Corp., New York, N. Y.
Kadletz, J. A., Gen. Elec. Co., Schenectady, N. Y.
Morch, W. J., Ebasco Services, Inc., New York, N. Y.
Nielsen, C. E., Ebasco Services, Inc., New York, N. Y.
Rudi, W. J., U. S. Navy, New York, N. Y.
Terwilliger, C. F., Gen. Elec. Co., Bloomfield, N. J.
Wappler, D., Pub. Serv. Elec. & Gas Co., Newark, N. J.

4. Southern

Axelsson, R. (Reelection), Fraser-Brace Engg. Co., Inc., Camden, Ark.
Baugh, J. F., Natl. Elec. Coil Co., Pineville, Ky.
Bryant, C. K., Sr., Bryant Elec. Repair Co., Inc., Gastonia, N. C.
Davis, R. K., U. S. Maritime Com., Wilmington, N. C.
Donadieu, F. A., La. Pr. & Lt. Co., New Orleans, La.
Hanley, R. J., U. S. Army, Robbins Field, Ga.
Harris, J. N., Tenn. Valley Auth., Knoxville, Tenn.
Hebert, H., Hebert Bros., Plaquemine, La.
Jones, C. T., South-Eastern Underwriters Assoc., Atlanta, Ga.
Kinard, A. R., U. S. Navy Yard, Charleston, S. C.
Kline, K. H., Tenn. Eastman Corp., Oak Ridge, Tenn.
Runkles, M. V., Jr., U. S. Maritime Com., Wilmington, N. C.
Sharp, J. D., Jr., General Elec. Co., Atlanta, Ga.
Smith, C. L., Jr., U. S. Navy Yard, Charleston, S. C.
Voight, J. P. (Reelection), Box 557, Summerville, S. C.
Wallace, C. M., Duke Pr. Co., Gastonia, N. C.

5. Great Lakes

Armstrong, F. C., Pub. Serv. Co. of Northern Ill., Joliet, Ill.
Bard, R. L., Commonwealth Edison Co., Chicago, Ill.
Booth, W. L., U. S. Navy, Chicago, Ill.
Brown, W. H., Keystone Steel & Wire Co., Peoria, Ill.
Bullard, H. M., Commonwealth Edison Co., Chicago, Ill.
Elliott, M. F., Pub. Serv. Co. of Northern Ill., Harvey, Ill.
Ely, O. G., Kingsbury Ord. Plant, La Porte, Ind.
Foulkes, H. J., Pub. Serv. Co. of Northern Ill., Streator, Ill.
Horkay, T. E., Central Ill. Elec. & Gas Co., Rockford, Ill.
Jeswick, M. J., Gen. Elec. Co., Chicago, Ill.
Kalm, A. V. (Reelection), Commonwealth Edison Co., Chicago, Ill.
Kartalia, M. P., Square D Co., Milwaukee, Wis.
Lauritsen, C. N. (Reelection), Pub. Serv. Co. of Northern Ill., Joliet, Ill.
Leinberger, P. H., Square D Co., Milwaukee, Wis.
Linn, G. J. (Reelection), Commonwealth Edison Co., Chicago, Ill.
Mekelburg, L. J., Square D Co., Milwaukee, Wis.
Osborne, R. H., Pub. Serv. Co. of Northern Ill., Joliet, Ill.
Phinney, L. W., Control Corp., Minneapolis, Minn.
Rood, G., Cutler-Hammer, Inc., Milwaukee, Wis.
Roth, F. H., Commonwealth Edison Co., Chicago, Ill.
Sherwood, B. C. (Reelection), Commonwealth Edison Co., Chicago, Ill.
Strai, B., Pub. Serv. Co. of Northern Ill., Chicago, Ill.
Sickel, S. J., Northwestern Pub. Serv. Co., Huron, S. Dak.
Thompson, M. J., Ind. & Mich. Elec. Co., South Bend, Ind.
Weaver, J. W., U. S. Maritime Com., Chicago, Ill.
Wieseman, T. R., Louis Allis Co., Milwaukee, Wis.

6. North Central

James, L. S. (Reelection), Pub. Serv. Co. of Colo., Boulder, Colo.
Stromquist, T. A., U. S. Bur. of Reclamation, Denver, Colo.

7. South West

Brill, G. F., Gulf States Util. Co., Beaumont, Texas.
Ellis, D. S., Southern Pac. R.R., Houston, Texas.
Graham, O. W., Texas Co., Houston, Texas.
Hickerson, H. H., Boeing Airplane Co., Wichita, Kans.
Sheets, D. H., Line Material Co. St. Louis, Mo.
Smith, F. D., Dallas Pr. & Lt. Co., Dallas, Texas.
Summers, O. V., Texas Pipe Line Co., Houston, Texas.

8. Pacific

Bell, R. L., Westinghouse Elec. & Mfg. Co., San Francisco, Calif.
Bowen, F. A., Westinghouse Elec. & Mfg. Co., Los Angeles, Calif.
Coombs, J. C., U. S. Engineers, Sacramento, Calif.
Elmore, J., Arden Farms Co., Los Angeles, Calif.
Freitas, E. A., Northrop Aircraft, Inc., Hawthorne, Calif.
Ginochio, E., Pacific Gas & Elec. Co., Sacramento, Calif.
Harding, J. G., Pacific Gas & Elec. Co., San Francisco, Calif.
Hausler, E. H. (Reelection), Westinghouse Elec. & Mfg. Co., San Francisco, Calif.
Hersam, E. C. (Reelection), Pacific Gas & Elec. Co., San Mateo, Calif.
Leithold, A. A., Food Mchry. Corp., Riverside, Calif.
McGinty, E. A. (Reelection), Pacific Gas & Elec. Co., Sacramento, Calif.
Mitchell, F. C., Kern Mutual Tel. Co., Taft, Calif.
Plesset, E. H., Douglas Aircraft Co., Inc., Santa Monica, Calif.
Rees, I. J., Fed. Pr. Com., San Francisco, Calif.
Sargent, W. S., Los Angeles Water & Pr. Dept., Los Angeles, Calif.
Steere, S. H., Southern Calif. Tel. Co., Los Angeles, Calif.
Swengel, F. M., Goodyear Aircraft Corp., Litchfield Park, Ariz.
Van Antwerp, E. D., Allis-Chalmers Mfg. Co., Los Angeles, Calif.
Whitehead, S. K., Southern Calif. Tel. Co., Los Angeles, Calif.
Whiteley, E., Pacific Gas & Elec. Co., San Francisco, Calif.
Wolbers, H. L., Southern Calif. Tel. Co., Los Angeles, Calif.
Young, F. L. (Reelection), Southern Calif. Tel. Co., Los Angeles, Calif.

9. North West

Aldrich, K. B. (Reelection), Bonneville Pr. Adm., Portland, Oreg.
Aust, G. E., Bonneville Pr. Adm., Vancouver, Wash.
Brittain, V. M., Willamette Iron & Steel Corp., Portland, Oreg.
Carlson, J. L., Puget Sound Pr. & Lt. Co., Seattle, Wash.
Cooper, C. C., Gen. Elec. Co., Portland, Oreg.
Gadeholt, B., N. W. Elec. Co. & Pacific Pr. & Lt. Co., Portland, Oreg.
Gill, J. W., Puget Sound Bridge & Dredg. Co., Seattle, Wash.
Heller, C. F., U. S. Navy, Portland, Oreg.
Houston, C. M., Bonneville Pr. Adm., Vancouver, Wash.
Kuder, A. S. (Reelection), Washington Water Pr. Co., Spokane, Wash.
Meiggs, R. F., Willamette Iron & Steel Corp., Portland, Oreg.
Piggott, H. P., Montana Pr. Co., Great Falls, Mont.
Seat, A. W., Puget Sound Pr. & Lt. Co., Seattle, Wash.
Winters, B., Gen. Elec. Co., Seattle, Wash.

10. Canada

Dobesch, R. R., Elec. Sub-Lieut., R.C.N.V.R., Halifax, N. S., Can.
McCaslin, W. O., Mercury Mills, Hamilton, Ont. Can.
Patterson, J. G., Canadian Comstock Co. Ltd., Red Rock, Ont., Can.
Taylor, L. J., Can. Natl. Carbon Co., Ltd., Toronto, Ont., Can.

Elsewhere

Abreu, C. S. (Reelection), Cia. Matogrossense de Eletricidade, Brazil, Sao Paulo, S. A.
Aillaud, G. A., Gen. Motors de Mex., Mexico, D. F., Mex.
Darton, R. V., Johnson & Phillips, Ltd., London, England.
Garvey, R. J., Royal Aircraft Estab., Farnborough, England.
Wong, S. M., Metropolitan-Vickers Elec. Co., Ltd., Manchester, England.

Total to grade of Associate
United States and Canada, 153
Elsewhere, 6

OF CURRENT INTEREST

Bureau of Ships Creates Electronics Division

With electronic devices assuming a more important place in the fields of naval communication, navigation, ordnance, gunnery, and tactics, and in the general battle efficiency of the Navy's airplanes and ships, the Bureau of Ships has broadened the scope of its older radio division and renamed it the electronics division. Captain J. B. Dow, who has been responsible for the design, production, and installation of the Navy's electronic equipment for several years, has been appointed director of electronics.

Among the division's personnel of 1,200 are numbered some of the foremost electronic authorities and engineers in the country. The research organizations of government and industry have fully collaborated with the division's engineers in producing radio, radar, and sonar equipment to secure its primary objective of maintaining a technical superiority over enemy equipment. Commenting on the divisions' work, Captain Dow recently estimated "the research work in the electronic field started before the war and carried on at an accelerated rate since hostilities commenced has resulted in advancing the electronic art by at least ten years."

Signal Corps Institutes Relay Radio in France

A system of very high-frequency radio relay equipment has been introduced in France by the United States Army Signal Corps as an answer to the communications problem which arises when the stringing of wire cannot keep pace with the speed of the campaign.

This radio relay system consists of stations 25 to 100 miles apart, each beamed on the next. Police scout-car equipment which had been procured for expected police communications requirements in North Africa was found to be very well suited for radio relay systems. After the system was tested in North Africa, it was developed in the United States and England.

The actual combat-line communications are built around radio. In addition to the individual radio networks which each field unit has, every tank has a radio, and a certain number of infantrymen from each company are equipped with voice pack sets. For communication with the United States, a high-powered multichannel 40-kw Army transmitter which took 25 days to assemble has been installed in France.

This Army radio station, with its $2,000,000 worth of equipment, operates from batteries of radio and landline teletype machines and sends out approximately 400,000 words a day. Direct hookups with Washington, London, the Army world-wide radio communications system including Africa and Italy, and Army headquarters on the continent, make possible the transmission of impulses along supply lines over 4,000 miles long.

Homing Pigeons' Reactions to Radio Waves Tested

Support for the belief that radio waves affect the instincts of homing pigeons has been supplied by a recent series of tests made by the United States Army Signal Corps. These tests apparently prove that radio transmission confuses the birds and retards them in fulfilling their flying missions.

Three successive tests were made with three different groups consisting of ten birds each, all of similar type and training. The birds were taken to a loft about ten miles from their home lofts. In each test five birds were released while the radio station was transmitting and the second five were liberated with the station silenced. Those birds released while the station was transmitting seemed completely bewildered. They circled erratically, very close to the station, for 15 or 20 minutes, then took off uncertainly for their lofts, requiring a total of 42 to 52 minutes to complete the 10-mile flight. Those freed while the station was silent made the usual brief circling, then took off promptly for the home loft with no confusion, covering the distance in 18 to 21 minutes. All birds flew under practically identical conditions of wind and weather.

The results of all three tests were virtually the same. However, the Signal Corps expects to test many more pigeons before the evidence can be accepted as conclusive.

Shortage of Electricity in Holland. An order issued by the authorities in the city of s'-Hertogenbosch limits the use of electric current to one 25-watt lamp for six hours each day, thus illustrating the shortage of electricity in Holland's liberated area. Under this condition, if there are two families in one home, one 15-watt and one 9-watt lamp may be used, or, if three families are living in the same house, three nine-watt lamps. In addition, the use of electric heaters and irons, vacuum cleaners, and washing machines is prohibited.

INDUSTRY . . . . .

Three Turbines Scheduled for Mexican Power Plant

With the first turbine already installed and in operation, work on the second of three turbines destined for a Mexican hydroelectric power plant is now in process. These turbines will operate with the highest "head" for this type unit in the western hemisphere, according to Ralph Kelly, president of the Baldwin Locomotive Works, the manufacturer. They are part of the Ixtapantongo Development of the Comision Federal de Electricidad, located on the Tilostoc River, about 100 miles southwest of Mexico City, and will furnish power through the Mexican Light and Power Company. Each turbine is to supply 39,000 horsepower under head of 1,028 feet, and the total adc tional power generated will take Mexi City off present power rationing which lim citizens and industries to power for on eight of each 24 hours.

The unit is of the vertical-shaft Fran type provided with a butterfly valve and Pelton relief valve to prevent pressure ris for load rejection. As compared with th Tennessee Valley Authority development o the Tennessee River between Knoxville an Chattanooga, the power developed is almo the same, but the Mexican turbines requi only 372 cubic feet of water as against th 7,930 cubic feet for the TVA turbines, an the weight of the new turbine unit is on 260,000 pounds, a fraction of the weight the larger unit. The new turbines are fe by water from a diversion dam built at high level of the Tilostoc River.

New Ceramic Insulation Developed From Zircon

In order to cope with the shortage electrical insulators for ultrahigh-frequenc equipment, a new ceramic insulation know as zircon porcelain has been developed b the Westinghouse Electric and Manufactu ing Company.

High-voltage porcelains and similar soli insulations have undesirably high energ losses when subjected to voltages in meg cycle bands and the production of the ceram insulation, steatite porcelain, has been limite by the lack of usable talc, one of its ingre dients, and by the stringent conditions im posed on its processing.

The supply of mineral zircon is abundan as it is found in the sands of beaches in man parts of the world, including Florida, India Brazil, and Australia, and is a common con stituent of many igneous rocks. The re sultant zircon porcelain, which can b processed readily with standard equipmen is said to surpass other insulations in tensil strength, compressive strength, transvers strength, and ability to withstand moistur and heat shock.

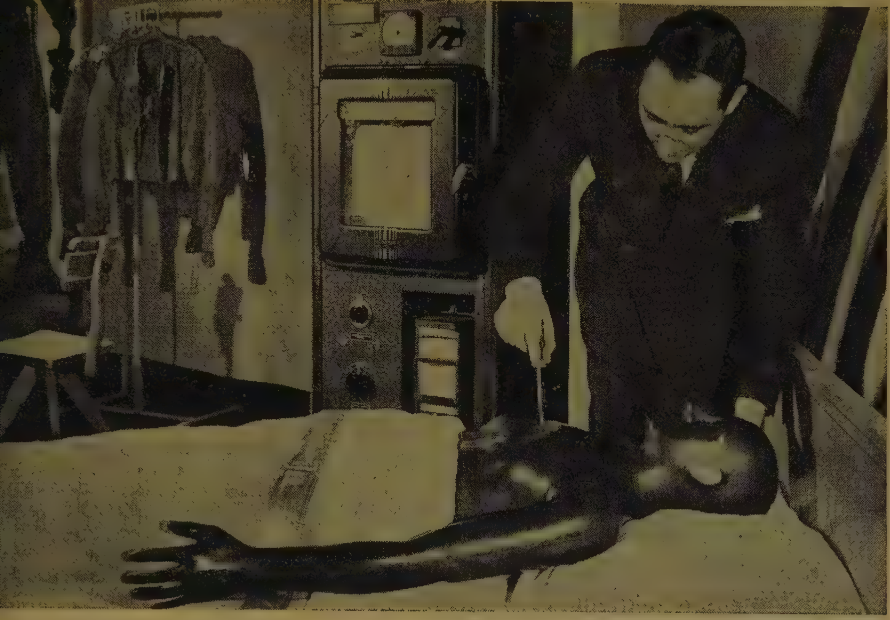
POSTWAR . . . .

FCC Releases Proposals for Frequency Allocation

Preliminary proposals of the Federa Communications Commission for dividin the postwar radio spectrum from 25,000 t 30,000,000 kilocycles among the two nu merous applicants for spectrum space ar contained in a report recently issued by th Commission.

Since the proposed allocations, based o public hearing held last fall, are only tenta tive, oral argument on their soundness an sufficiency will be heard by the Commissio commencing on February 14, 1945.

Heated Clothing Tested on Copper Man



ive feet $10^1/_2$ inches tall with a copper "skin" $^1/_{16}$ of an inch thick, this copper man ssembled according to dimensions furnished by the United States Army to the General lectric Company, Schenectady, N. Y., relieves human volunteers from suffering low emperatures during tests of electrically heated clothing and casualty blankets for the rmed Forces. A complicated system of electric wires connected to separate areas of ie copper head, torso, feet, and hands enables reproduction of the inconstant temerature of the human body. The amount of heat-generating energy to each of the 5 areas of the copper body can be controlled separately and the temperature can ange from subnormal to above normal. Aviators and bomber crews now can be omfortably and safely clad without subjecting human experimenters to the discomforts of high-altitude and low-temperature chambers

Aside from newcomers to the radio specums, the most notable changes in the resent groupings are the removal of freuency modulation from 42–50 to 84–102 egacycles and the contraction of comercial television from 18 channels six egacycles wide at intervals from 50 to 94 megacycles to six channels six megaycles wide at intervals from 44 to 84 megaycles and an extra six channels from 180 to 16 megacycles. However space for telesion experimentation with color pictures id higher-definition monochromes also is lotted between 480 and 920 megacycles in ie ultrahigh-frequency range.

The frequency-modulation broadcasting osition is shifted on the grounds that skyave interference in the lower region would e severe enough to impair the utility of equency modulation to the extent of rerding its full development. At this point ie Commission deviates from the Radio echnical Planning Board recommendation, ith the latter committed to the lower band channels. Twenty of the 90 channels signed to frequency modulation will be served for noncommercial educational use. ve such stations are now in use, eight lditional applications are on file, and a idespread interest and support for this oposal has been expressed by educational stitutions, according to the report. Oppoents of this change of position for frequency odulation argue that existing transmitters ust be remodeled and that most receiver sets will be outmoded, since only a few can be converted. However, the Commission contends that, even without a new spectrum allotment, normal progress expected after the war will bring this about. The change is not contemplated, it adds, until sets which can tune in on the new wave lengths are generally available.

Television was one of the most controversial questions discussed at the hearings, the report states. Many witnesses demanded that it be moved altogether into the ultrahigh-frequency range, and others objected to the reduction in the total amount of space granted. The Commission wished to keep television within the lower cycles, until receiver sets for the higher ranges were perfected and ready for general distribution.

Heavy demands of the aviation industry for radio channels above 25 megacycles in the postwar period are allowed by the Commission almost exactly as specified. In this connection, the importance of aviation to transportation and economic prosperity and the dependence of aviation upon radio for safety are emphasized.

Increased numbers of channels are suggested for amateur radio operation, police radio, fire-department use, and for miscellaneous emergency services. Channels for anticipated expansion of radio communication in business and between private citizens, for linking up isolated communities with telephone service, for industrial and medical service, and for general mobile traffic service also are set aside. The railroads are given a number of channels on their plea that radio will be a contribution to their greater postwar safety.

The Commission's report thanked the Radio Technical Planning Board for its aid, stating that most of that body's recommendations were embodied in the report. No dissenting report was filed by any of the Commissioners, because the report is not intended to represent the Commission's final decisions.

RMA Estimates Postwar Employment in Industry

The radio industry will provide postwar employment for about 68.6 per cent more men and women than its prewar employment, according to a recent survey made by the Radio Manufacturers Association. The employment total of the industry is expected to decrease only 39.8 per cent after a return to peacetime production because of the demand for radios to replace worn-out sets, as well as the anticipated postwar popularity of frequency-modulation receivers and, a little later, television. This will mean that 28.5 per cent of the present industry employees will be forced to seek work in another field, because of war contract cutbacks and the return of former employees now in the armed services. However, many of those now employed, such as housewives, will not continue working after the war.

The RMA survey was one of the first postwar employment studies made by a large industry. It includes figures from 202 companies, representing 64.9 per cent of the industry. This covers the largest and virtually all substantial manufacturers and represents about 80 per cent of industry employees.

EDUCATION . . .

University of Maryland to Have Aeronautical School

Plans for establishment of a college of aeronautical education and research and endowment of the Glenn L. Martin Aeronautical Research Foundation have been announced by the University of Maryland on receipt of an initial gift of $1,700,000 from The Glenn L. Martin Company for this purpose.

Of the total amount, $1,500,000 plus $750,000 in State funds, will be allotted for the construction of facilities. The remaining $200,000 will be used at the outset to endow the Research Foundation.

Gift to Brown University. Expansion of the engineering laboratory facilities by the addition of a second floor to the Engineering Laboratory Building at Brown University will be accomplished as the result of a gift of $30,000 from the Hammel-Dahl Company, Providence, R. I. The gift was prompted by the co-operation between research workers at the University and the company in the performance of the latter's Government contracts during 1944.

JOINT ACTIVITIES

United Engineering Trustees, Inc., Issues Report; Elects Officers

A resurgence of the planning for future adequate housing for the engineering societies which was suspended by the advent of the war is forecast for the coming year in the annual report of UET, Inc., submitted to the AIEE and the other participating societies by F. Malcolm Farmer, president.

With the growth of society membership from about 9,000 in 1907 to its present 70,000, finding even sufficient headquarters space in the Engineering Societies Building rapidly is becoming a problem, and the inadequacy of the building for meetings is evidenced in the accepted practice of holding annual meetings in more commodious hotels. According to the report there is urgent need for decisions on such questions as:

1. Should the present Engineering Societies Building be modernized and made adequate for the exclusive occupancy of the Founder Societies.

2. Should a new building be erected on a new site to be occupied only by the Founder Societies.

3. Should a large building project to constitute an engineering center be undertaken on the present site, or some other suitable site; one which would provide headquarters and ample meeting facilities for all engineering societies as well as the Founder Societies.

4. Should the latter project be further expanded to include the Engineers' Club and offices for practicing engineers and engineering concerns, that is, revive the plan seriously studied in 1931 by a joint committee of the UET and the Engineers' Club?

Though meeting facilities will be improved slightly for the immediate future by the return to their original purpose of several meeting halls which had been converted temporarily into emergency offices for the war projects of one society, this offers no lasting solution to the space problem.

All available office space in the building now is occupied by strictly engineering organizations, with about 61 per cent of the space allotted to offices. During the past year meeting halls have been used for military instruction and meetings, and the library has been in daily use by the War Department and members of the Armed Forces making special studies. Replacement of broken waterpipes and new risers in the wiring system were the only major repairs made during the year to the building which otherwise is in excellent physical condition. Both fire and extended coverage insurance is carried and war damage insurance has been renewed automatically so that all contingencies can be met, the report states in covering the subject of the general utility of the building.

Increased revenue from meeting-hall rentals and reduction to token payments of $500 of the interest payments formerly made to the Founder Societies have left the UET with a credit balance of $286.70 for the year, compared with a debit balance of $1,615.24 for the previous year. This has been effected despite increased labor costs and emergency repairs. Though a rise in building labor costs is expected, it is hoped that meeting-hall rental and space-assessment income will offset the rise. The report adds that repairs now are charged against current income rather than the building-depreciation reserve fund, thus allowing the latter to accumulate against the diminishing value of the Societies building at the maximum rate obtainable from the yearly allocation of $20,000. The book value of investments at the close of the fiscal year was $1,503,175.93 and the market value was $1,524,293.64, or approximately 101$^1/_2$ per cent of book value, against last year's market value which was 102 per cent of book value.

In order to clarify the prevalent confusion about the division of its income between building expenses and other activities, the UET has broken down its expenses into approximated percentages. Of the total assessments paid by the Founder and associate societies, about 16 per cent goes to the replacement of building equipment (depreciation fund) 62 per cent toward operating the Engineering Societies Building, and 22 per cent to operating UET, Inc., as a corporation, which is the custodian of the joint Founder Society funds and an agency through which certain joint activities of the Founder Societies are carried on.

It is hoped, the report concludes, that the almost certain expansion of postwar cooperation among engineering societies will be reflected in an increased use of UET in the interest of economy of overhead expenses and a minimum of duplicated effort.

In addition to the executive officers previously announced (*EE, Dec '44, p 458*) the following were elected to the board of trustees for terms expiring in 1948: R. E. Dougherty, Ralph B. Williams, J. Schuyler Casey, and Everett S. Lee.

Members of the finance committee are:

George L. Knight, *chairman*
J. Schuyler Casey
C. R. Jones
Albert Roberts
Arthur S. Tuttle
R. B. Williams
F. M. Farmer, *ex officio*

Members of the real estate committee are:

A. L. Queneau, *chairman*
J. P. H. Perry
Everett S. Lee
R. E. Dougherty
Henry A. Lardner
F. M. Farmer, *ex officio*

Members of the executive committee are:

F. Malcolm Farmer, *chairman*
Arthur S. Tuttle
A. L. Queneau
George L. Knight
Albert Roberts

Engineering Foundation Summarizes Year's Research; Elects Officers

Officers elected for the year 1944–45 at the recent annual meeting of the Engineering Foundation, joint research agency of the Founder Societies, are:

Chairman, A. L. Queneau
Vice-chairman, A. B. Kinzel
Director, Edwin H. Colpitts
Secretary, John H. R. Arms

Members of the executive committee in addition to the chairman, vice-chairman, and secretary of the Foundation are: J. Schuyler Casey, R. H. Chambers, R. E. Dougherty.

Members of the Foundation board for 1944–45 with the dates of expiration of their terms are:

Trustees elected by the board of trustees of UET, Inc.
A. L. Queneau, AIME, 1945
J. Schuyler Casey, ASME, 1947
C. R. Jones, AIEE, 1947
R. E. Dougherty, ASCE, 1948
President, UET, Inc., ex officio
F. Malcolm Farmer,
Members-at-large
O. E. Buckley, AIEE, 1946
R. H. Chambers, ASCE, 1947
A. B. Kinzel, AIME, 1947
Members nominated by Founder Societies
F. F. Colcord, AIME, 1946
E. M. T. Ryder, ASCE, 1946
F. Malcolm Farmer, AIEE, 1947
Joel D. Justin, ASCE, 1947
A. A. Potter, ASME, 1947
L. W. Chubb, AIEE, 1948
E. A. Prentis, Jr., AIME, 1948
W. Trinks, ASME, 1948

Members of the research procedure committee are:

L. W. Chubb, *chairman*, Foundation representative
E. A. Prentis, Jr., Foundation representative
H. E. Wessman, ASCE
W. M. Peirce, AIME
W. Trinks, ASME
W. A. Lewis, AIEE

Chairman Queneau was appointed to represent the Foundation on the executive board of the National Research Council.

The personnel of other committees as appointed or reappointed at this meeting follows:

Iron Alloys Committee

Jerome Strauss, *chairman;* vice-president, Vanadium Corporation of America, New York, N. Y., representing American Society for Testing Materials.

Lyman J. Briggs, director, National Bureau of Standards, represented by J. G. Thompson, senior metallurgist, National Bureau of Standards, Washington, D. C.

James H. Critchett, vice-president, Union Carbide and Carbon Research Laboratories, New York, N. Y., representing American Electrochemical Society.

John Johnston, director of research, United States Steel Corporation, Kearny, N. J., representing American Iron and Steel Institute.

James T. Mackenzie, chief metallurgist, American Cast Iron Pipe Company, Birmingham, Ala., representing American Foundrymen's Association.

R. R. Sayers, director, United States Bureau of Mines, represented by R. S. Dean, assistant director, United States Bureau of Mines, Washington, D. C.

Bradley Stoughton, professor emeritus, Lehigh University, Bethlehem, Pa., representing American Society for Testing Materials.

Wilfred Sykes, president, Inland Steel Company, Chicago, Ill., member-at-large.

T. H. Wickenden, assistant manager, development and research division, International Nickel Company, Inc., New York, N. Y., representing Society of Automotive Engineers.

Frank T. Sisco, *consultant*, assistant secretary, AIME, New York, N. Y.

Welding Research Council

C. A. Adams, *chairman;* E. G. Budd Manufacturing Company, Philadelphia, Pa.

A. S. Albright, acting chief of research, Detroit Edison Company, Detroit, Mich.

David Arnott, vice-president, American Bureau of Shipping, New York, N. Y.

H. C. Boardman, *vice-chairman;* director of research, Chicago (Ill.) Bridge and Iron Company.

Everett Chapman, P. O. Box 387, Coatesville, Pa.

J. H. Critchett, vice-president, Union Carbide and Carbon Research Laboratories, New York, N. Y.

J. J. Crowe, assistant to vice-president and operating manager, Air Reduction Sales Company, New York, N. Y.

C. E. Davis, vice-president, Alan Wood Steel Company

Conshohocken, Pa., representing the American Iron and Steel Institute.

C. L. Eksergian, chief engineer, Budd Wheel Company, Detroit, Mich.

A. J. Ely, mechanical engineer, Standard Oil Development, Elizabeth, N. J.

F. H. Frankland, 271 Madison Avenue, New York, N. Y.

T. S. Fuller, works laboratory, General Electric Company, Schenectady, N. Y.

Isaac Harter, vice-president, Babcock and Wilcox Company, Barberton, Ohio.

D. S. Jacobus, advisory engineer, 93 Harrison Avenue, Montclair, N. J.

G. F. Jenks, 232 Avondale Avenue, Los Angeles, Calif.

Carl M. Loeb, Jr., vice-president, Climax Molybdenum Company, New York, N. Y.

Arthur E. Pew, vice-president, Sun Oil Company, Philadelphia, Pa.

G. A. Reinhardt, director of metallurgy and research, Youngstown (Pa.) Sheet and Tube Company, Youngstown, representing AISE.

Charles Schenck, research engineer, Bethlehem (Pa.) Steel Company, representing AISE.

A. C. Weigel, vice-president, Combustion Engineering Company, New York, N. Y.

Clyde Williams, National Defense Research Committee, Battelle Memorial Institute, Columbus, Ohio.

A. R. Wilson, engineer of bridges, Pennsylvania Railroad, Philadelphia.

R. E. Zimmerman, vice-president, United States Steel Corporation of Delaware, Pittsburgh, Pa.

W. Spraragen, *executive secretary*, Welding Research Council, New York, N. Y.

ANNUAL REPORT

The Engineering Foundation, established in 1914, completed its 30th fiscal year on September 30, 1944, and the chairman's report of the year's activities was presented to the AIEE and the other Founder Societies by A. L. Queneau at its annual meeting. The book value of the capital funds of the Foundation on September 30, 1944, was $962,000 compared with $959,000 on September 30, 1943. The income for the fiscal year 1943–44 was $35,472.76, as compared with $35,160.38 for the previous year 1942–43. For the fiscal year 1943–44 disbursements amounted to $22,750.78, as compared with $31,790.20 for year 1942–43. The balance on September 30, 1944, was $41,014.85 as compared with $28,292.87 on September 30, 1943.

As is customary the Foundation has contributed to a number of research projects in diverse fields of engineering and to the support of certain agencies having as their objective the advancement of the profession of engineering. Preference is given to projects of a fundamental nature, which normally would not be undertaken by industrial research organizations. In certain cases, where a group of industries are concerned, participation enables the Foundation to serve, as it were, as a catalysing agent for an undertaking, mainly supported by contributions from industry. In addition projects have been scrutinized with regard to their bearing on the war and have been encouraged only as they promised to contribute to the war effort. Because the Government through its various agencies is able to support any research project of probable importance to the war effort, the demand for support from an agency such as the Foundation is limited. Coupled with this is the fact that competent research personnel has been withdrawn largely from educational institutions to serve in Army, Navy, and other Government research and development activities. The result is a continuing lessened demand upon the Foundation's funds for the support of research projects and a reduction in the number of such projects. It is clear, however, that in the years following the war the need for engineering research in many fields will be recognized even more fully and in that period beyond any question the Foundation could employ profitably a much larger income than will be available from its present capital funds.

During the year 1943–44, work on seven projects has continued, for the year 1944–45 grants were recommended for continuation of work upon five projects and the initiation of three new projects.

A summary of the project with which AIEE has been directly concerned follows.

Welding Research Council. (Foundation grant $4,000. Chairman, Comfort A. Adams, E. G. Budd Manufacturing Company, Philadelphia, Pa.)

As a result of its eight years of operation the Welding Research Council has emerged as the recognized medium for co-operative welding research in this country, according to the report. Most of the interested engineering societies, trade associations, government departments, and industries interested in welding have come to look upon the Council as their welding-research organization. Many of the project committees of the Council have direct contacts in their particular fields through common membership with the technical committees of the American Welding Society, other engineering societies, and government departments. In this way their codes, specifications, and standards, and governmental reports immediately reflect the findings and knowledge gained through the research work of the Council. For example the "Handbook" and educational books of the American Welding Society have made full use of the reports of the Council.

Research has been continued actively under the various committees. In the opinion of the chairman the greatest single accomplishment of the Welding Research Council during the year was the arrival at a better understanding of the fundamentals of the two major problems which confront the welding industry, namely, weldability and weld stresses. Concise reports of the work of each of the project committees of the Council follow:

Aircraft Welding Committee (Chairman, G. S. Mikhalapov)—The Welding Research Council's committee in this field comprises the major scientific research talent engaged in aircraft-welding-research investigations. The American Welding Society has a somewhat similar body concerned with the standardization of the use of welding in aircraft construction. The work of the research committee forms a basis for the standardization activities. The interested government departments are co-operating and, in fact, supplying most of the necessary funds, although some of the member companies are contributing to the program.

Some nine reports have been published by the committee in the *Welding Research Supplement*, and there have been several confidential reports, not released for publication, issued by the National Advisory Committee for Aeronautics. These cover the investigations at Rensselaer Polytechnic Institute, Troy, N. Y., and at Battelle Memorial Institute, Columbus, Ohio.

Fatigue Testing (Structural) (Chairman, Jonathan Jones)—The principal subcommittees met in the spring of 1944 and the main committee in April 1944 to prepare extensions of the program at the University of Illinois, Urbana. Two bulletins, 344 and 350 of the Engineering Experiment Station, University of Illinois, appeared, giving the results of tests on butt, fillet, and plug welds. Three reports have been issued by the main committee. A fourth report on "The Fatigue Strength of Fillet, Plug, and Slot Welds," is receiving final review before publication, Pilot tests have been made to ascertain whether fatigue strength is reduced by the metallurgical heat effects of welding with mechanical stress raisers eliminated. The findings will be presented in the form of a paper at the forthcoming meeting of the Welding Society. These tests already are being followed by a more complete program aimed at exploring all important variables. A new large financial contributor, the American Iron and Steel Institute, has been added. In 1943, subcommittees on flexural members, and on bridge-reinforcement details were organized, both headed by representatives of the Association of American Railroads. The programs of these swo subcommittees have formed a large part of the work in 1944.

High Alloys Committee (Chairman, S. L. Hoyt)—The committee has established two fellowships, one at Carnegie Institute of Technology, Pittsburgh, Pa., for work on stress corrosion of stainless steels and the other at Stevens Institute of Technology, Hoboken, N. J., for work on corrosion of stainless steels. The following reports were published during the year:

A first "Report on Stress Corrosion Cracking of Stainless Steel in Chloride Solutions," by M. A. Scheil, O. Zmeskal, J. Waber, and F. Stockhausen in October 1943; and a report, "Studies on Stress Corrosion Cracking of Austenitic Stainless Steels, Types 347 and 316," by M. A. Scheil and R. A. Huseby in August 1944.

Resistance Welding Committee—The resistance welding committee's activities have been divided between two subcommittees, one of them recently organized under the chairmanship of S. L. Hoyt, to study problems relating to flash welding of aluminum and its alloys, and the other on the general fundamentals of spot welding under the chairmanship of F. R. Hensel. The work of the last-named subcommittee has been continuing for several years at Rensselaer Polytechnic Institute under the supervision of Wendell F. Hess. During the past year the resistance welding activities of that laboratory have been concerned with the spot welding of heavy plate materials, including principally the more hardenable types used for military purposes. There also has been investigational work on the spot welding of SAE 1020 and *X*-4130 steels in the 0.125-inch gauge, and another investigation has involved the seam welding of monel metal.

Structural Steel Committee (Chairman, Lamotte Grover)—As in most university research, the investigations centered in the several universities have been retarded seriously by lack of research personnel. One report on "Tests of Welded Top-Plate and Seat Building Connection" by J. L. Brandes and R. M. Mains appeared in the March *Supplement*. Otherwise investigations at Le-

high University, Bethlehem, Pa., and at the Carnegie Institute of Technology have come to a standstill. Work continues on a limited scale at Columbia University, New York, N. Y., on the study of structural members under impact loads and the effect of impact on residual stresses in structural joints, particularly butt splices in heavy H-sections.

The committee initiated several new programs of investigations, one of which is the effect of residual stresses in different types of joints commonly used in ship construction and the related effect of propagation of cracking. The behavior of residual stresses in welded joints in thick material and under severely restrained conditions also will be studied, using specially constructed box-girder specimens. Both investigations will be carried out at the United States Bureau of Standards.

The United States Navy is co-operating by making available the results of experiments dealing with causes of brittle fractures under high stress concentrations, with and without strain aging under restrained conditions found in thick materials.

University Research Committee (Chairman, H. C. Boardman)—The university research committee also has been handicapped considerably because of lack of personnel to undertake welding research work under its direction. Although a great many welding investigations are being carried out at the universities, most of these have become affiliated either with government-sponsored projects or with the larger and immediate projects of the Welding Research Council.

Weldability Committee (Chairman, A. B. Kinzel)—Both Lehigh University and Rensselaer Polytechnic Institute, having worked out the metallurgical problem comprised in the heat-affected zone next to the weld and the factors involved therein, have concentrated on the problem of cracking in the weld proper, it being understood that the latter problem is associated intimately with the previous one. At Lehigh University a new type of specimen has been evolved, which will be described in detail as soon as government regulations permit. This specimen gives a quantitative index for the susceptibility to cracking of welds made in steels of various analyses and of the effect of welding-rod composition and welding procedure on this cracking tendency. It promises to be of very practical value in weld evaluation and specifications. At Rensselaer Polytechnic Institute the problem has been attacked from a more basic point of view with precise measurements of welding conditions and stresses which tend to or do produce cracks in the weld. This work already has shed considerable light on the important factors affecting this phenomenon. It is expected that as in the case of the studies of the zone next to the weld, the combined work of Lehigh University and Rensselaer Polytechnic Institute will give both, a better understanding of the phenomenon and a tool of direct application for the welding engineer.

Plans are under way for continuing at Battelle Memorial Institute weldability investigations with respect to carbon manganese steel. In addition to the work at Battelle Memorial Institute on bead hardness and bead-bend tests, financed by the committee, the following co-operators have furnished results on work on the same materials performed at their own expense: Naval Research Laboratories, covering a study of five types of weldability tests; Carnegie Illinois Steel Company, investigating tee-bend tests; and Climax Molybdenum Research Laboratories, making end-quench hardenability tests.

Weld Stress Committee (Chairman, E. Chapman)—Progress has been made in the study of the very complex problem of weld stresses. At the Massachusetts Institute of Technology, Cambridge, the committee has continued its investigations on the measurement and distribution of stresses across the thickness of a thick plate. Biaxial fatigue studies have been continued at Illinois Institute of Technology, Chicago.

The committee has formulated comprehensive programs on subjects and at institutions as indicated:

1. Residual stresses produced by various welding procedures, Massachusetts Institute of Technology.
2. Peening investigations, Polytechnic Institute of Brooklyn, N. Y.
3. Residual stresses under biaxial and triaxial condition and the use of high-speed rotating disk, Massachusetts Institute of Technology.
4. Strength and ductility of steel under conditions of multiaxial tension, Case School of Applied Science, Cleveland, Ohio.
5. Studies of the flow, fracture, and relaxation of steels under combined stresses at high temperature, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
6. Hemispherical shells subjected to static pressures, Pennsylvania State College.
7. Biaxial fatigue studies, Illinois Institute of Technology.

IEE Offers Reduced Subscription Rates

The Institution *Journal* and *Science Abstracts*, publications of the Institution of Electrical Engineers, London, England, are now available to AIEE members at a 50 per cent reduction in the regular subscription rate.

The *Institution Journal* consists of three parts: "General"; 12 issues beginning in January at two dollars per year, "Power Engineering"; six issues beginning in February at three dollars per year, and "Radio and Communication Engineering"; four quarterly issues beginning in March at two dollars per year. All three parts may be obtained for six dollars annually.

Science Abstracts, published in association with the British Physical Society, the American Physical Society, and the AIEE, is issued in two sections, "Physics Abstracts" and "Electrical Engineering Abstracts." The volume consists of 12 monthly issues starting in January. Each section is $3.50 per year or six dollars for both sections.

AIEE members desiring either or both publications should make payment through the AIEE.

Seattle Engineering Groups Form Puget Sound Council

Organization of the Puget Sound Council of Engineering and Technical Societies, a group of various engineering, architectural, and technical sections and chapters in Seattle, Wash., and vicinity, has been announced by C. H. Cutter (A '28), chairman of the AIEE Seattle Section.

The council is patterned after the national Engineers' Council for Professional Development and is the result of an idea brought back by Mr. Cutter from the AIEE summer technical meeting, St. Louis, Mo. Under this plan, local sections or chapters of national societies are banded together in a joint council. It is expected that membership will include approximately 20 societies. Representatives of AIEE on the Puget Sound Council are N. A. Carle (A '06, F '13) who is chairman and R. E. Kistler (A '17, M '30) who is secretary. R. L. Rockwell (A '13, M '22) vice-chairman, is representing the American Society of Mechanical Engineers. Treasurer of the council is LaMonte Shorett.

The Puget Sound Council's aim is to present the unified engineering profession's views on public matters to commissions or other public bodies. It expects to take an active part in the planning and construction of postwar projects, to concern itself with legislation having to do with code standardization, engineering licensing, and other nonpolitical matters, and to take an active interest in the re-establishment in civilian life of the engineers returning from military service.

LIBRARY • • • • • •

OPERATED jointly by the AIEE and the other Founder Societies, the Engineering Societies Library, 29 West 39th Street, New York 18, N. Y., offers a wide variety of services to members all over the world. Information about these services may be obtained on inquiry to the director.

Library Reports for 1943–44; New Officers Chosen

At the recent annual meeting of the Engineering Societies Library board, E. F. Church, Jr., was appointed chairman for 1944–45, and R. H. Barclay (F '28) was appointed vice-chairman. Harrison W. Craver was reappointed director of the library and secretary of the board.

Members of the library board are:

Terms expiring October 1945
Edward P. Hamilton, ASCE
W. A. Mudge, AIME
John Blizard, ASME
W. I. Slichter, AIEE

Terms expiring October 1946
Charles E. Trout, ASCE
Thomas T. Read, AIME

Terms expiring October 1947
J. K. Finch, ASCE
E. F. Church, Jr., ASME
George L. Knight, AIEE

Terms expiring October 1948
James W. Laist, AIME
P. H. Hardie, ASME
Nelson S. Hibshman, AIEE

Members-at-large
Sydney H. Ball
Robert H. Barclay
George F. Felker

Members of the executive committee for 1944–45 are:

E. P. Hamilton	George L. Knight
John Blizard	T. T. Read

ANNUAL REPORT

The annual report of the Engineering Societies Library for the year 1943–44 was submitted by Harrison W. Craver, director,

Operation of Library

Maintenance revenue	$48,945.44	
Maintenance expenditures	43,970.93	
Credit balance for year 1943–44	4,974.51	
Credit balance from previous years	18,134.16	
Credit balance September 30, 1944		$23,108.67
Service bureau revenue	$25,852.76	
Service bureau expenditures	18,909.23	
Credit balance for year 1943–44	6,943.53	
Credit balance from previous years	8,227.48	
Credit balance September 30, 1944		15,171.01
Total net operating credit balance cumulated to September 30, 1944		$38,279.68

Library Services

	1941–42	1942–43	1943–44
Visitors	23,734	22,260	21,992
Other users	10,648	13,579	15,147
Total	34,382	35,839	37,139
Photostat orders	3,046	3,487	4,029
Photostat prints made	31,254	38,702	53,518
Telephone inquiries	6,097	6,689	6,700
Borrowers	650	1,055	1,133
Books lent	846	1,393	1,533
Searches and copies	103	86	114
Translations	35	30	53
Total acquisitions	10,163	10,286	8,104
Books reviewed	498	420	364
Library inventory			
Volumes in library	154,873	156,780	158,521
Maps	7,859	7,872	8,392
Searches	4,525	4,565	4,654
Total	167,257	169,216	171,567

to the AIEE and the other Founder Societies in tabular form. The accompanying tables show an increase in the total number of users and a greater proportion of nonvisitors using the library. The demand for photostats also has been a record one. Additions to the book collection have declined because of wartime curtailment of supplies from Europe. Expenditures were kept well within the budgeted amounts.

OTHER SOCIETIES •

CEMA Opens Headquarters In Toronto, Canada

A Canadian Electrical Manufacturers Association which will perform for the Canadian industry a function similar to that filled by the National Electrical Manufacturers Association in the United States has established its headquarters in Toronto. The new organization generalized its objects as the promotion and furthering of the interests of manufacturers of electrical products and the interests of the public in manufacturing, engineering, safety, transportation, and other matters.

Specific aims listed by the association are:

1. To increase the amount and improve the quality of electrical service to the public.

2. To promote the standardization of electrical products.

3. To collect information relating to the industry and to disseminate such information to members of the Association and to the public.

4. To appear for the members of the CEMA before and to co-operate with legislative committees, government departments, and other bodies on matters affecting the industry.

5. To attain improved production, enlarged distribution, and increased efficiency in the use of electrical products.

The Association already has inaugurated its program of activities by setting up a War Assets Corporation to assist in the disposal of war equipment surpluses and is developing a Farm Electrification Council to sponsor the expansion of electrical services in rural areas. The Association hopes to realize this latter project by encouraging simplification of design and improved distribution with their consequent reduction in cost.

An effort will be made to avoid having the services offered by CEMA overlap those of the Canadian Manufacturers Association and the Canadian Standards Association.

R. D. Kerby of Toronto, formerly executive assistant to the president of Research Enterprises Ltd., and a founder and first president of the Canadian Automobile Chamber of Commerce, has been appointed general manager of CEMA.

ASME Council Approves Proposed Organization Changes

The recent report of the special committee on society organization structure of the American Society of Mechanical Engineers, which considered recommendations concerning geographic divisions and representation, committee responsibility, efficiency of organization, and the responsibilities of the secretary of the society, was approved by the ASME council at its meeting of December 1, 1944. This report proposed several changes in the structure of the society.

Geographically, there will be a division of the United States into eight districts, each headed by a vice-president nominated by, and responsible for, that district. This system is patterned after that in successful operation in the AIEE and is intended to provide a more direct representation than does the present ASME scheme. Although no change will be made in the method of electing managers, the title of director has been substituted for that of manager as one which is used more uniformly to designate such offices, and the elections of both vice-presidents and directors will be staggered as to time. To effect this, four vice-presidents will be elected each year and two directors at large each year.

In the matter of committee responsibility, in order to allow both the council and the executive committee more freedom for the consideration of general policy and the formulation of long-term plans for the benefit of the society, boards of control will be set up with jurisdiction over committees in their respective fields. All existing operating committees will report to one of the boards recommended, and the board, in turn, will submit reports to the Council, as only matters of policy need the council's attention and action.

No change is contemplated in important agencies of the society such as the boiler code and test code committees, as it is important that neither their responsibilities nor their prestige be curtailed. The function of the boards of control is to be that of responsible co-ordinating and screening agents to which is delegated authority from the council to pass on matters handed up to them and to make recommendations for council approval of codes and standards and for committee appointments.

In addition, to contribute to the efficiency of the headquarters organization, it has been recommended that several competent assistants be added who are preferably younger than 40 years and in no case older. Although some difficulty is expected in finding suitable men at this time, the end of the war should make available much excellent material.

AAAS Elects Officers for 1945

Charles F. Kettering (F '14) vice-president of General Motors Corporation, Dayton, Ohio, was elected president of the American Association for the Advancement of Science at the annual meeting of the association held in December. At that time vice-presidents for the various branches of science were elected. Those elected are:

Mathematics—E. P. Lane, University of Chicago, Ill.

Physics—R. C. Gibbs, Cornell University, Ithaca, N. Y.

Chemistry—Henry Eyring, Princeton, N. J.

Astronomy—J. J. Nassau, Case School of Applied Science, Cleveland, Ohio.

Geology and Geography—Arthur Beven, University of Virginia, Charlotteville.

Zoology—Carl G. Hartman, University of Illinois, Urbana.

Botany—F. D. Kern, Pennsylvania State College, State College.

Anthropology—A. Irving Hallowell, Northwestern University, Evanston, Ill.

Psychology—Florence Goodenough, University of Minnesota, Minneapolis.

History and Philosophy of Science—John F. Fulton, Yale University, New Haven, Conn.

Engineering—George A. Stetson, *Mechanical Engineering*, New York, N. Y.

Medical Sciences—Warfield T. Longcope, Johns Hopkins University, Baltimore, Md.

Agriculture—William Albrecht, University of Missouri, Columbia.

Education—H. H. Remmers, Purdue University, Lafayette, Ind.

Otis Caldwell of the Boyce Thompson Institute is general secretary of the association, F. R. Moulton is permanent secretary, and W. E. Wrather of the United States Geographical Survey is treasurer.

RMA Cancels Winter Conference and Probably Trade Show

In compliance with the recent request of James F. Byrnes, director of the Office of War Mobilization for voluntary reduction in travel and attendance at industry meeting, trade shows, and conferences, cancellation of the midwinter conference of the Radio Manufacturers Association has been announced by R. C. Cosgrove, president of RMA.

All committee and group meetings planned for the conference originally scheduled for February 19 to 21 in New York, N. Y., have been abandoned, but a meeting of the board

of directors will be held on February 21, as it involves less than 50 persons, the limit recommended for such meetings by the committee executing Director Byrnes' order. Other division and committee meetings involved in the blanket cancellation of the midwinter conference may be held separately later with minimum travel and hotel requirements.

An RMA trade parts show planned by the RMA contingent upon the defeat of Germany by April 1 probably will be canceled at the association's next board of directors meeting, since the OWM request singles out postwar trade shows for disapproval.

Plans for the annual RMA war-production conference and annual membership meeting scheduled for next June in Chicago, Ill., are going forward on a much reduced scale. It is expected that attendance will be limited to official delegates and groups directly connected with the war program.

AIME Cancels General Meeting

In conformation with the recently published request of James F. Byrnes, Director, War Mobilization and Reconversion, to conserve transportation the American Institute of Mining and Metallurgical Engineers has announced the cancellation of its 162d general meeting, scheduled for New York, N. Y., February 19–22, 1945.

The technical papers which were to have been presented at the meeting will be made available to members through the various AIME publications.

ASRE Periodical Will Appear in Fall of 1945

The first issue of *Refrigeration Abstracts*, a new publication venture for the American Society of Refrigerating Engineers, is scheduled for sometime in the fall of 1945. The magazine, which will be issued biannually for the duration of the war, will condense current refrigeration publications of engineering and scientific value, encompassing both English- and foreign-language material. After the war, when paper supply will not be a determining factor, it is planned to increase the yearly issues to six.

J. Mack Tucker, associate professor of mechanical engineering at the University of Tennessee and a contributor to *Refrigerating Engineering* and the "Refrigerating Data Book" has been chosen editor of the *Abstracts*.

IRE Initiates Building-Fund Campaign. A campaign to raise a $500,000 building fund in anticipation of postwar expansion of its service to the electronic and communication industries, was inaugurated by the Institute of Radio Engineers during its winter technical meeting held in New York, N. Y., in January. Actual building plans will remain flexible to permit establishing the new quarters jointly with other engineering and scientific societies, if this should prove desirable, the directors of the society announced.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Influence of Research on Engineering Developments

To the Editor:

The third paragraph of L. W. Chubb's article, "Influence of Research on Engineering Developments" (*EE, Dec '44, p 443–4*) contains astonishing statements regarding the World War I status of airplanes and automotive transport.

In 1918 hundreds of airplanes were functioning, and thousands of American trucks were delivering supplies to the front in France. Of course, railroads handled the bulk of the freight in the rear areas because of their greater efficiency.

Since 1918 outstanding improvements have been made in these types of transportation, particularly in airplanes, as a result of experience as well as scientific research. However, if available, railroads still handle the bulk of the freight for the same reason as before.

C. T. WELLER (M '21)

(Electrical engineer, General Electric Company, Schenectady, N. Y.)

Postwar Curriculums in Electrical Engineering

To the Editor:

I think the article, "Postwar Curriculums in Electrical Engineering," by R. G. Kloeffler (*EE, Oct. '44, p. 364–7*) and the letter to the editor from H. L. Abbott (*EE, Dec. '44, p. 458–9*) are very constructive.

I hesitate a little to give you my own opinion, as I did not have the fortune of being brought up in this country. However, in some respects it may be of interest to compare the European practice with the one in use here.

One condition for graduation which I think is very important is the required proof of one full year's work in factories in basic operations. It is so arranged abroad that there is a lapse of six months between graduation from high school and the start of the first semester of college in order to allow a half year's work before going to college; the balance of the work usually is arranged during the summer vacations. To illustrate the point I give you my own schedule:

First 26 weeks:	
Four weeks each—	Foundry
	Pattern shop
	Machine shop: lathe
Two weeks each—	Machine shop: milling machine
	Tool room: hardening and precision grinding
	Forge shop
	Sheet-metal work
Six weeks—	General assembly including welding
Next three months:	All different operations in an electric instrument plant
Next two months:	A-c and d-c winding, motor, and transformer assembly
Final two months:	General work in electric shop of power plant

Besides this factory practice, the electrical engineering curriculum contains considerably more mechanical-engineering subjects as the two departments are two subdivisions of one major department abroad. A basic course in civil engineering is compulsory and accounting is taught with considerable detail.

The fact that a much smaller percentage of students goes to high school in Europe allows a certain selectivity which results in teaching a major portion of basic subjects in high school, freeing the freshman year of college for more advanced subjects. At the same time the higher level of the high school takes care of the literary, humanitarian, and biological subjects advocated in the previous articles.

JACK M. NOY (A '41)

(Electrical engineer, Climax Molybdenum Company of Pennsylvania, Langeloth)

NEW BOOKS • • •

The following new books are among those recently received from the publishers. Books designated ESL are available at the Engineering Societies Library; these and thousands of other technical books may be borrowed from the library by mail by AIEE members. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books. All inquiries relating to the purchase of any book reviewed in these columns should be addressed to the publisher of the book in question.

Battery-Electric Vehicles. By S. M. Hills. George Newnes, Ltd., Tower House, Southampton Street, Strand, London, W.C.2, England, 1943. 206 pages, illustrated, 9 by $6^1/_4$ inches, cloth, 12*s*.6*d*. (ESL.)

This book deals with all types of battery-operated electric vehicles and their accessories, including light and heavy trucks, tractors, locomotives, busses, passenger cars, and so forth. Batteries, charging equipment, and care and maintenance are discussed as well. The possible fields of use are pointed out, and British practice is thoroughly reviewed. There is a bibliography which is confined to British publications. This is the first book on the subject in 25 years.

Henley's Twentieth Century Book of Formulas, Processes and Trade Secrets. Edited by G. D. Hiscox, 1944; revised and enlarged edition by T. O. Sloane. Norman W. Henley Publishing Company, New York, N. Y., 1944. 865 pages, illustrated, $8^1/_2$ by $5^1/_2$ inches, cloth, $4. (ESL.)

This well-known collection of recipes, formulas, and processes has been revised again. New formulas have been added and new sections included on plastics and on photography. Old formulas have been replaced by better ones.